PNL--8324

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FORT LEWIS NATURAL GAS AND FUEL OIL ENERGY BASELINE AND EFFICIENCY RESOURCE ASSESSMENT

J. R. Brodrick[a]
K. K. Daellenbach
G. B. Parker
E. E. Richman
T. J. Secrest
S. A. Shankle

February 1993

Prepared for
the U.S. Department of Energy
Federal Energy Management Program
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Richland, Washington 99352

(a) U.S. Department of Energy
Washington, D.C.

PREFACE

The goal of the U.S. Department of Energy (DOE) Federal Energy Management Program (FEMP) is to facilitate energy-efficiency improvements at federal facilities. This is accomplished by a balanced program of technology development, energy-efficiency resource and energy supply assessment, and facility modernization. Technology development focuses upon the tools and procedures used to identify and evaluate efficiency improvements, such as the federal life-cycle cost analyses. For efficiency resource and energy supply assessment, FEMP provides metering equipment and trained analysts to federal agencies exhibiting a commitment to understanding and improving energy use efficiency and reducing energy costs.

The U.S. Army Forces Command (FORSCOM) has tasked Pacific Northwest Laboratory (PNL),[a] as the lead laboratory supporting the FEMP mission, to provide technical assistance to characterize and modernize energy systems at FORSCOM installations. With funding from FORSCOM, FEMP, and the Bonneville Power Administration, PNL has undertaken development of a comprehensive integrated energy resource assessment approach and applied it at Fort Lewis, a FORSCOM installation near Tacoma, Washington. The Fort was chosen as a pilot site for developing this approach.

This report documents the natural gas and fuel oil baseline and efficiency resource assessment potential for major sectors and end uses at Fort Lewis. It is a companion document to PNL-7763,[b] which provides an estimate of the electricity use baseline and efficiency improvement potential at the Fort. Because the site was chosen as a pilot site for developing this approach, it was anticipated that some energy-efficiency measures would be implemented during the time period of the assessment and documentation.

(a) Pacific Northwest Laboratory is operated for the U.S. Department of Energy by Battelle Memorial Institute under Contract DE-AC06-76RLO 1830.
(b) Secrest, T. J., et al. 1991. Fort Lewis Electric Energy Baseline and Efficiency Resource Assessment. PNL-7763, Pacific Northwest Laboratory, Richland, Washington.

Therefore, the efficiency resource may be less than identified in this assessment. Nevertheless, significant efficiency improvement opportunities that are identified in this document remain at the site.

EXECUTIVE SUMMARY

The mission of the U.S. Department of Energy (DOE) Federal Energy Management Program (FEMP) is to lead the improvement of energy efficiency and fuel flexibility within the federal sector. Through the Pacific Northwest Laboratory (PNL), FEMP is developing a fuel-neutral approach for identifying, evaluating, and acquiring all cost-effective energy projects at federal installations; this procedure is entitled the Federal Energy Decision Screening (FEDS) system. Through a cooperative program between FEMP and the Army Forces Command (FORSCOM) for providing technical assistance to FORSCOM installations, PNL has been working with the Fort Lewis Army installation to develop the FEDS procedure. The natural gas and fuel oil assessment contained in this report was preceded with an assessment of electric energy usage that was used to implement a cofunded program between Fort Lewis and Tacoma Public Utilities to improve the efficiency of the Fort's electric-energy-using systems.

This report extends the assessment procedure to the systems using natural gas and fuel oil to provide a baseline of consumption and an estimate of the energy-efficiency potential that exists for these two fuel types at Fort Lewis. The baseline is essential to segment the end uses that are targets for broad-based efficiency improvement programs. The estimated fossil-fuel efficiency resources are estimates of the available quantities of conservation for natural gas, fuel oils #2 and #6, and fuel-switching opportunities by level of cost-effectiveness. The intent of the baseline and efficiency resource estimates is to identify the major efficiency resource opportunities and not to identify all possible opportunities; however, areas of additional opportunity are noted to encourage further effort.

BASELINE ENERGY USE

Fort Lewis is a FORSCOM installation whose primary mission is to provide training and combat readiness for assigned units and other military and reserve forces. Approximately 25,000 persons are housed on the Fort, and the daytime population is approximately 35,000 persons. Of the stock of 4457 buildings having 23.9 million square feet of floorspace, approximately 3918 buildings with 22 million square feet of floorspace are served by natural gas and fuel oil. An estimated 2,205 of these buildings are residential, having 5.9 million square feet of floorspace and containing 3505 living units.

The annual fossil-fuel consumption is about 2.5 trillion Btu, of which 43% is in the form of natural gas (annual average of 10 to 11 million therms), 31% is in the form of fuel oil (annual average of about five million gallons) and the remainder in the form of electricity. The annual cost of energy supplied to the Fort is over $12 million, of which about $4.5 million is for natural gas and about $3.1 million is for fuel oil.

Natural gas and fuel oil are used almost exclusively for space and water heating. Residential space heat is provided primarily by natural gas, although some units have electric heat. About 10% of residential water heat is provided by natural gas; the Fort plans to increase this share as electric water heaters are replaced. Non-residential building space and water heat are provided both by district systems and boilers located within the buildings. Eight central boilers provide heat for the associated district systems, which supply space and water heat to approximately 24% of the non-residential buildings accounting for about 35% of the non-residential floorspace. Buildings that have their own boilers generally have two, one each to provide space heat and water heat.

Of the total fossil-fuel energy provided to all buildings and for all other uses, 57% is consumed within building boundaries, 27% is provided to buildings through the district systems, and 17% is in the form of distribution losses. Natural gas accounts for 56% of total fossil energy consumption, 60% of which is consumed within building boundaries and 40% in the district systems. Virtually 100% of fuel oil #2, which accounts for 23% of total fossil energy consumption, is consumed within building boundaries. Fuel oil #6 makes up 21% of total fossil energy use and is allocated 100% to the district systems. Several of the building types were larger consumers of fossil fuels, both directly and from the distribution system. These types are barracks (20% of total fossil-fuel use), residential (18%), motor pool (12%), "other" (11%), and office/administration (10%). These five building types account for about 70% of the Fort's fossil energy consumption.

EFFICIENCY RESOURCE

Sixty-one efficiency measures were identified for investigation as candidates for potential implementation at Fort Lewis; 35 were analyzed for efficiency potential and cost-effectiveness. The 35 measures considered were applied to the three building sectors (residential, non-residential not on a district thermal system, and non-residential connected to a district thermal system) and the district thermal system and analyzed by type of fuel consumed. The final number of cases for which measures were analyzed was 110, and 67 were determined to be cost-effective, e.g., had a positive net present value (NPV). Four of the 67 measures involved switching from fuel oil or electricity to natural gas, and the remaining 63 were efficiency improvements.

Table S.1 summarizes the life-cycle cost-effective efficiency resource by end-use sector and fuel type. This table provides the energy-use reduction, new load due to fuel-switching, net energy reduction in million Btu (MBtu), capital cost, value of annual energy savings, and associated NPV.

As shown in Table S.1, implementing the 67 measures would provide an estimated reduction in fossil-fuel use of 319,000 MBtu/year and reduce the annual fuel bill by $2.3 million with an NPV of nearly $41.6 million. This would provide an 18% decrease in annual fossil-fuel energy use at the Fort and reduce the annual fossil-fuel energy bill by 31%.

Because of the restrictions currently placed on renovation/retrofit of "temporary" wood-constructed buildings in the North Fort area at Fort Lewis, the resource assessment excludes these buildings. These buildings are in the non-residential/non-system building sector and represent approximately 660 buildings with over 2 million square feet. Table S.2 shows the potential life-cycle cost-effective fossil-fuel efficiency for the entire Fort if, in the future, these buildings are renovated.

Implementing all 67 measures in the entire Fort, including the temporary buildings in the North Fort, would provide an estimated reduction in fossil

TABLE S.1. Annual Cost-Effective Fossil-Fuel Efficiency Resource by Sector and Fuel Type (excluding North Fort Area)

	Energy-Use Reduction (MBtu)	New Load (MBtu)	Net Energy-Use Reduction (MBtu)	Initial Capital Cost (1991 $)	Value of Annual Energy Savings (1991 $)	NPV of Strategy (1991 $)
By Sector (including fuel-switching)						
District System	107,113	0	107,113	767,721	561,912	12,428,655
Non-Residential/Non-System	198,953	107,005	91,948	3,131,186	985,129	14,616,789
Non-Residential/System	131,129	45,121	86,008	2,239,400	602,134	12,628,201
Residential	34,014	0	34,014	737,588	173,485	1,923,070
TOTAL	471,210	152,126	319,084	6,875,895	2,322,660	41,596,716
By Fuel						
Fuel Oil #2	48,430	0	48,430	705,199	359,189	5,609,758
Fuel Oil #6	117,242	0	117,242	2,165,664	767,936	15,982,261
Natural Gas	136,947	0	136,947	1,751,850	428,251	5,522,441
Fuel-Switching (elec to gas)	12,679	14,587	-1,908	282,757	47,400	344,164
Fuel-Switching (#2 to gas)	102,828	92,418	10,410	1,901,778	466,782	7,112,589
Fuel-Switching (#6 to gas)	53,083	45,121	7,962	68,647	252,940	7,023,987
TOTAL	471,210	152,126	319,084	6,875,895	2,322,497	41,595,201

TABLE S.2. Annual Cost-Effective Fossil-Fuel Efficiency Resource for the Entire Fort (including North Fort Area) by Sector and Fuel Type

	Energy Use Reduction (MBtu)	New Load Use (MBtu)	Net Energy Reduction (MBtu)	Initial Cap. Cost (1991 $)	Energy Savings (1991 $)	NPV of Strategy (1991$)
By Sector (including fuel-switching)						
District System	107,113	0	107,113	767,721	561,912	12,428,655
Non-Residential/Non-System	261,787	141,187	120,600	4,144,725	1,313,461	19,643,023
Non-Residential/System	131,129	45,121	86,008	2,239,400	602,134	12,628,201
Residential	34,014	0	34,014	737,588	173,485	1,923,070
TOTAL	534,044	186,308	347,736	7,889,434	2,650,992	46,622,950
By Fuel						
Fuel Oil #2	66,348	0	66,348	963,191	492,306	7,690,764
Fuel Oil #6	117,242	0	117,242	2,165,664	767,936	15,982,261
Natural Gas	143,814	0	143,814	1,800,905	450,224	5,826,929
Fuel-Switching (electricity to gas)	12,679	14,587	-1,908	282,757	47,400	344,164
Fuel-Switching (#2 to gas)	140,877	126,600	14,277	2,608,269	640,187	9,754,845
Fuel-Switching (#6 to gas)	53,083	45,121	7,962	68,647	252,940	7,023,987
TOTAL	534,044	186,308	347,736	7,889,434	2,650,992	46,622,950

fuel use of nearly 350,000 MBtu annually, reduce the annual fuel bill by about \$2.7 million, and have an NPV of over \$46 million. This would provide a 20% decrease in annual fossil energy use at the Fort and reduce the annual fossil-fuel energy bill by 34%.

The non-residential, non-system building sector has the greatest efficiency potential, followed by actions in the district system and non-residential system. As a whole, improvements to the district system show the quickest return, followed by actions in the non-residential non-system, non-residential system, and residential buildings sectors.

The energy efficiency and fuel-switching measures having a positive NPV are given by end-use sector and by fuel type in Table S.3.

A suggested strategy to pursue implementation of these actions consists of the following:

- fund the most cost-effective options (highest value index [VI]) out of operation and maintenance funds to free up budget resources to invest in the higher cost actions
- seek cofunding from the natural gas utility and/or funding through a performance contract to implement the fuel-switching measures
- develop budget request proposals for additional funds to implement higher cost measures.

This assessment is a first cut at estimating the fossil-fuel energy potential at the Fort. As such, the results should be very useful in identifying, prioritizing, and implementing future energy efficiency improvements. The results should not be used to draw conclusions regarding the cost-effectiveness of marginal actions, except that such actions require more detailed analysis.

TABLE S.3. Energy-Efficiency and Fuel-Switching Measures Having Positive Net Present Values, by Sector

	Energy-Use Reduction (MBtu)										
	Natural Gas	Fuel Oil #2	Fuel Oil #6	Elec-tricity	Total	Initial Cap. Cost (1991 $)	Present Value of O&M Costs (1991 $)	Annual Energy Savings (MBtu)	Value of Annual Energy Savings (1991 $)	NPV of Strategy (1991 $)	Value Index
District System											
District Thermal Distrib.											
Ins buried pipe-main dist line	0	9	0	0	9	202	0	9	69	1,020	5.06
Ins above grnd dist pipe	0	16	0	0	16	80	0	16	118	2,006	25.06
Water-to-water heat exchanger	2,262	0	0	0	2,262	5,255	0	2,262	4,750	109,725	20.88
Ins Hot Water Storage Tanks	0	16	0	0	16	177	0	16	116	1,871	10.57
Minimize Losses in Steam Lines	0	0	19,580	0	19,580	103,976	0	19,580	128,246	2,956,654	28.44
Minimize Losses in Steam Lines	0	4	0	0	4	35	0	4	28	454	13.12
Insulate Hot Fuel Oil Pipes	0	0	4,186	0	4,186	37,715	0	4,186	27,418	616,612	16.35
Minimize Losses in Steam Lines	5,098	0	0	0	5,098	31,541	0	5,098	10,705	198,346	6.29
Ins Hot Water Storage Tanks	0	0	10,366	0	10,366	117,089	0	10,366	67,899	1,503,337	12.84
Ins above grnd dist pipe	13,265	0	0	0	13,265	44,056	0	13,265	27,856	474,328	10.77
Ins Hot Water Storage Tanks	6,754	0	0	0	6,754	76,292	0	6,754	14,184	236,274	3.10
Ins buried pipe-main dist line	4,019	0	0	0	4,019	86,807	0	4,019	8,440	99,177	1.14
Ins buried pipe-main dist line	0	0	6,167	0	6,167	133,221	0	6,167	40,397	830,864	6.24
Water-to-water heat exchanger	0	0	4,903	0	4,903	36,323	0	4,903	32,115	730,103	20.10
Ins above grnd dist pipe	0	0	30,469	0	30,469	94,952	0	30,469	199,572	4,667,884	49.16
Subtotal	31,398	45	75,671	0	107,113	767,721	0	107,113	561,912	12,428,655	16.19
Non Residential/Non System											
Bldg. Aux. Heating											
Infrared heaters	12,083	0	0	0	12,083	68,414	0	12,083	38,665	563,381	8.23
Bldg. Envelope											
Ins floor above crawl space	0	14,492	0	0	14,492	220,577	0	14,492	107,530	1,669,923	7.57
Ins floor above crawl space	566	0	0	0	566	8,609	0	566	1,810	20,141	2.34
Ins int brick surface walls	0	88	0	0	88	9,446	0	88	655	2,064	0.22
Insulate attic ceilings	0	2,174	0	0	2,174	165,432	0	2,174	16,130	118,152	0.71
Insulate suspended ceilings	0	1,010	0	0	1,010	56,628	0	1,010	7,494	75,131	1.33
Boilers											
Automatic electric dampers	7,496	0	0	0	7,496	46,410	0	7,496	23,987	334,607	7.21
Feedwater economizers	102	0	0	0	102	3,639	0	102	326	1,546	0.42
Fire-tube turbulators	721	0	0	0	721	1,176	0	721	2,307	35,472	30.16
Ins above grnd dist pipe	0	14,213	0	0	14,213	71,604	0	14,213	105,463	1,782,553	24.89
Ins above grnd dist pipe	6,911	0	0	0	6,911	34,815	0	6,911	22,114	316,456	9.09
Ins Hot Water Storage Tanks	6,816	0	0	0	6,816	76,984	0	6,816	21,813	269,492	3.50
Ins Hot Water Storage Tanks	0	14,018	0	0	14,018	158,330	0	14,018	104,010	1,670,286	10.55
Water-to-water heat exchanger	0	106	0	0	106	4,506	0	106	784	9,285	2.06

TABLE S.3. (contd)

	Energy-Use Reduction (MBtu)										
	Natural Gas	Fuel Oil #2	Fuel Oil #6	Elec-tricity	Total	Initial Cap. Cost (1991 $)	Present Value of O&M Costs (1991 $)	Annual Energy Savings (MBtu)	Value of Annual Energy Savings (1991 $)	NPV of Strategy (1991 $)	Value Index
Fuel Switch											
Elec to gas DHW - CR	-14,587	0	0	12,679	-1,908	282,757	-231,686	-1,908	47,400	344,164	1.22
Infrared heaters	-43,358	51,000	0	0	7,642	81,406	0	7,642	239,459	4,519,407	55.52
Oil to conv gas boiler	-49,060	51,827	0	0	2,768	1,820,371	0	2,768	227,323	2,593,182	1.42
Water Heating											
Ins Service Hot Water Pipes	0	657	0	0	657	10,512	0	657	4,878	75,249	7.16
Ins Service Hot Water Pipes	112	0	0	0	112	1,794	0	112	359	3,910	2.18
Low Flow Shower Heads	0	1,564	0	0	1,564	6,890	0	1,564	11,604	197,124	28.61
Low Flow Shower Heads	318	0	0	0	318	885	0	318	1,017	15,265	17.24
Subtotal	-71,880	151,150	0	12,679	91,948	3,131,186	-231,686	91,948	985,129	14,616,789	4.67
Non Residential/System											
Bldg. Aux. Heating											
Infrared heaters	8,760	0	0	0	8,760	55,533	0	8,760	18,396	245,074	4.41
Bldg. Envelope											
Ins int brick surface walls	0	0	272	0	272	29,195	0	272	1,781	13,319	0.46
Install storm windows	0	0	194	0	194	26,236	0	194	1,268	4,024	0.15
Insulate suspended ceilings	0	0	821	0	821	46,360	0	821	5,375	81,917	1.77
Boilers											
Air atom. burners/LEA burners	0	0	9,239	0	9,239	901,444	0	9,239	60,518	542,844	0.60
Auto blowdown w/ heat recovery	5,470	0	0	0	5,470	200,928	0	5,470	11,487	23,944	0.12
Auto blowdown w/ heat recovery	0	0	5,544	0	5,544	218,914	0	5,544	36,311	647,659	2.96
Automatic electric dampers	6,480	0	0	0	6,480	4,514	0	6,480	13,608	270,771	59.98
Automatic electric dampers	0	22	0	0	22	47	0	22	163	2,835	59.95
Automatic electric dampers	0	0	4,184	0	4,184	5,618	0	4,184	27,407	648,447	115.41
Boiler tuneup	0	22	0	0	22	0	1,368	22	163	1,515	(a)
Feedwater economizers	2,369	0	0	0	2,369	48,397	0	2,369	4,975	49,858	1.03
Feedwater economizers	0	0	2,310	0	2,310	90,991	0	2,310	15,130	270,081	2.97
Feedwater economizers	0	7	0	0	7	336	0	7	51	565	1.68
Flue gas analyzer	9,117	0	0	0	9,117	132,595	0	9,117	19,146	242,214	1.83
Flue gas analyzer	0	0	9,239	0	9,239	93,373	0	9,239	60,518	1,350,916	14.47
Maintenance of economizers	2,369	0	0	0	2,369	79,573	0	2,369	4,974	18,661	0.23
Maintenance of economizers	0	7	0	0	7	336	0	7	51	565	1.68
Maintenance of economizers	0	0	2,310	0	2,310	90,991	0	2,310	15,130	270,081	2.97
Oxygen trim control	0	0	4,805	0	4,805	130,722	179,072	4,805	31,470	441,236	3.38

TABLE S.3. (contd)

	Energy-Use Reduction (MBtu)					Initial Cap. Cost (1991 $)	Present Value of O&M Costs (1991 $)	Annual Energy Savings (MBtu)	Value of Annual Energy Savings (1991 $)	NPV of Strategy (1991 $)	Value Index
	Natural Gas	Fuel Oil #2	Fuel Oil #6	Elec-tricity	Total						
Fuel Switch											
Infrared heaters	-45,121	0	53,083	0	7,962	68,647	0	7,962	252,940	7,023,987	102.32
Water Heating											
Ins Service Hot Water Pipes	0	0	160	0	160	2,559	0	160	1,045	22,386	8.75
Ins Service Hot Water Pipes	122	0	0	0	122	1,953	0	122	257	2,729	1.40
Low Flow Shower Heads	0	0	2,494	0	2,494	5,986	0	2,494	16,337	383,896	64.13
Low Flow Shower Heads	1,730	0	0	0	1,730	4,152	0	1,730	3,633	68,676	16.54
Subtotal	-8,704	58	94,654	0	86,008	2,239,400	180,440	86,008	602,134	12,628,201	5.64
Residential											
Bldg. Aux. Heating											
Setback Thermostat Controls	19,374	0	0	0	19,374	218,155	0	19,374	98,809	1,297,193	5.95
Bldg. Envelope											
Ins perimeter of slab	586	0	0	0	586	5,901	0	586	2,988	39,930	6.77
Ins perimeter of slab	0	6	0	0	6	61	0	6	45	676	11.13
Insulate attic ceilings	13,346	0	0	0	13,346	507,808	0	13,346	68,063	536,020	1.06
Water Heating											
Ins Service Hot Water Pipes	144	0	0	0	144	2,315	0	144	735	8,962	3.87
Low Flow Shower Heads	558	0	0	0	558	3,349	0	558	2,845	40,290	12.03
Subtotal	34,008	6	0	0	34,014	737,588	0	34,014	173,485	1,923,070	2.61
TOTAL	-15,179	151,258	170,325	12,679	319,084	6,875,895	-51,246	319,084	2,322,660	41,596,716	6.05

(a) Value Index not defined, because capital cost is zero.

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FIGURES

TABLES

1.0 INTRODUCTION

1.1 PROJECT DESCRIPTION

Under the National Energy Conservation and Policy Act (as amended 1988), the federal government is required to reduce energy use in its facilities 10% per square foot, relative to 1985 levels, by 1995. Executive Order 12759, issued in April 1991, increased the energy reduction goal to 20% of the 1985 levels by the year 2000. Relative to the facilities of the Department of Defense, the National Defense Authorization Act of Fiscal Year 1991 (HR 4731, Sec 2851) further defines energy performance goals, financial criteria on projects, and the disposition of energy-cost savings. In response to these directives, energy-efficiency programs are in development to facilitate the implementation of technologies and practices that reduce facility energy-use requirements.

A major obstacle to reducing energy use in large federal installations is the current inability to characterize energy consumption by major sector and end use in detail sufficient to enable more than limited efficiency acquisition efforts. These installations are typically the size of small cities and, for the most part, energy use is not metered except at the installation level. Due to this complexity, the correct choice of projects is not obvious to the site managers, thus hesitation results. On the other hand, projects have been initiated at some federal installations but reflect a quick-fix approach based on simple payback that may not be in the best long-term interests of the site.

The mission of DOE's Federal Energy Management Program (FEMP) is to lead the improvement of energy efficiency and fuel flexibility within the federal sector. Through PNL, FEMP is developing a fuel-neutral approach for identifying, evaluating, and acquiring all cost-effective energy projects at federal installations. In addition, FEMP has a cooperative program with the U.S. Army Forces Command (FORSCOM) for providing technical assistance to FORSCOM installations. FEMP and FORSCOM have agreed to cost-share activities in developing innovative approaches to energy efficiency at the latter's installations. One of those installations is Fort Lewis, near Tacoma, Washington.

This analysis and report was undertaken by PNL under the direction of FEMP and FORSCOM as a pilot project, to develop a systematic approach with which to identify energy-efficiency potential in large federal installations and to methodically evaluate the situation at Fort Lewis. This approach will be refined and used to support energy-efficiency acquisition programs in other major federal sector installations in the U.S. and abroad.

This report describes the assessment of the natural gas and fuel oil energy-efficiency resource potential for major sectors and end uses at the Fort. Developing the baseline was essential to segment the end uses that are targets for broad-based efficiency improvement programs. An estimate of the efficiency resource is presented to reflect the available quantity of resource at different price ranges. The baseline and efficiency resource estimates did not identify all possible areas of opportunity, but instead identified the majority of the resource. Areas of additional opportunity are noted, to encourage further effort.

1.2 SITE CHARACTERIZATION

Fort Lewis is a FORSCOM installation whose primary mission is to provide training and combat readiness for assigned units and other military and reserve forces. The Madigan Army Medical Center is a major tenant that provides medical care to patients and medical training and research for Army and other personnel. Fort Lewis is also responsible for three subinstallations that support the training and readiness missions.

Fort Lewis proper is located on nearly 87,000 acres of property south of the city of Tacoma, Washington. Approximately 25,000 persons are housed on the Fort, and the daytime population is approximately 35,000 persons.

Of the estimated stock of 4457 buildings with 23.9 million square feet of floorspace, it is estimated that 3918 with 22 million square feet of floorspace are served by natural gas and fuel oil. Of these buildings 2,205 are residential, having 5.9 million square feet of floorspace and containing 3505 living units.

The annual fuel consumption is about 2.5 trillion Btu, of which 43% is in the form of natural gas (annual average of 10 to 11 million therms) and 31% is in the form of fuel oils (annual average of about five million gallons). The annual cost of energy supplied to the Fort is over $12 million, of which about $4.5 million is for natural gas and about $3.1 million is for fuel oils.

Natural gas and fuel oil are used almost exclusively for space and water heating. Residential space heat is provided primarily by natural gas, although some units have electric heat. About 10% of residential water heat is provided by natural gas, and the Fort plans to increase this share as electric water heaters are replaced. Non-residential building space and water heat are provided both by district systems and boilers located within the buildings. Eight central boilers provide heat for the associated district systems, which supply space and water heat to approximately 24% of the non-residential buildings accounting for about 35% of the non-residential floorspace. These boilers are fired by approximately equal shares of natural gas and fuel oil #6. Buildings that have their own boilers generally have two, one each to provide space heat and water heat; these are almost exclusively fueled with fuel oil #2.

1.3 SITE MODIFICATIONS

The Fort has recently experienced a decrease in troop levels, which will be offset over the next two years with the addition of 9,000 to 12,000 troops resulting from the closure of Fort Ord in California. This is expected to provide a small net increase in the Fort's population. No significant new construction is expected to accommodate the additional troops, although rehabilitation of existing facilities is likely. Although sections of the North Fort area have been targeted for demolition for several years, demolition activities have consistently been delayed.

1.4 REPORT ORGANIZATION

The text of this report provides a summary of the natural gas and fuel oil assessment. Section 2 provides the physical characterization of the facility and energy-use baseline by facility sector, end use, and fuel type.

Section 3 presents the analysis approach used to develop the resource assessment and provides the resource potential by level of cost-effectiveness for retrofit and fuel-switching actions identified by facility sector, end use, and fuel type. A summary of the findings and recommendations is presented in Section 4. Section 5 provides the sources and references used in the report. Readers interested in additional detail underlying this assessment are referred to the appendixes at the end of this report.

2.0 ENERGY-USE BASELINE

This section provides a characterization of the Fort Lewis physical and energy-supply and -using systems. The purpose is to develop a baseline of energy consumption by major energy-using sectors, end uses, and fuel types. The baseline is used to support the assessment of energy-efficiency potential.

2.1 CHARACTERIZATION OF PHYSICAL SYSTEMS

This section contains descriptive information on the Fort Lewis site and facilities. An overview of the site is followed by a tabulation of the building stock and other energy-consuming functions. A description of the district thermal systems serving sections of the Fort is provided in Section 2.2.

2.1.1 Site Description

As shown in Figure 2.1, the Fort's subsections are referred to as the Main Fort, Madigan, Logistics Center, and North Fort. The Main Fort contains the majority of administrative, operational and barracks facilities. The Madigan Army Medical Center comprises the old and new Madigan medical complexes. The Logistics Center is predominantly warehouse space, and the North Fort is largely vintage wooden barracks that provide temporary accommodations for training and transient personnel.

The climate is coastal in nature, with average summer (July) temperatures ranging from a low of 49°F to a high of 77°F and winter (January) temperatures averaging 31 to 44°F, providing for average heating and cooling degree days of 5709 and 94, respectively. Annual precipitation averages 51 inches per year, and the average windspeed is about 7 mph.

2.1.2 Facility Profile

In developing the baseline fossil-fuel use, the Fort was segmented into sectors, subsectors, and end uses to reflect major areas of consumption and efficiency potential. The three sectors identified were buildings, distribution and process functions, and field operations. These sectors were further segmented into subsectors and, in the case of buildings, end uses [i.e., space heating and domestic hot water (DHW)].

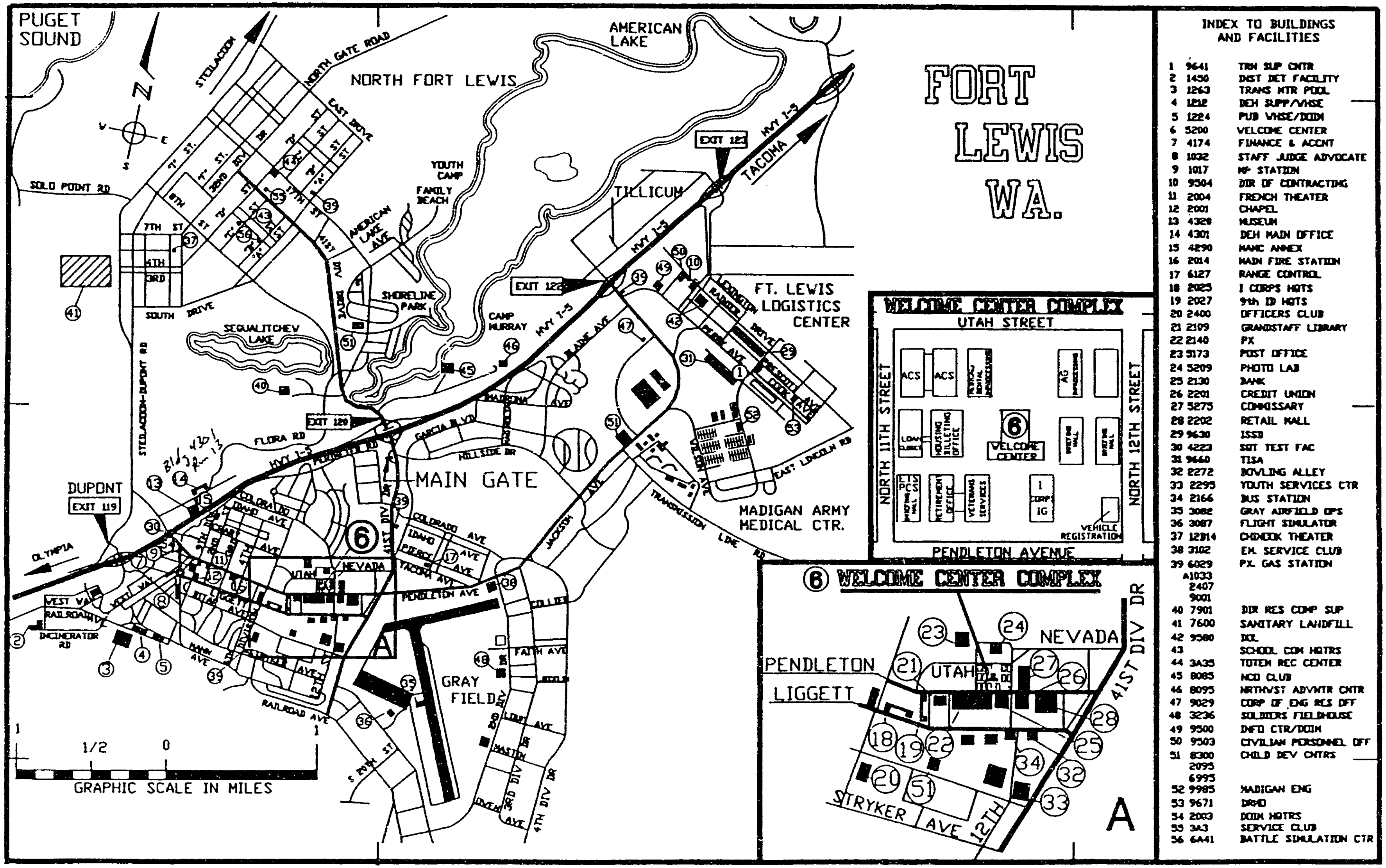

FIGURE 2.1. Fort Lewis Site Plan

Fossil-fuel delivery and meter records for Fort Lewis show that 3918 of the estimated 4457 buildings were served by fossil fuels. The differences are understood to be all-electric buildings, utility facilities without fossil-fuel service, buildings not on-line in 1989, or facilities closed or not served by fossil fuel in 1989.

Table 2.1 summarizes the entire building stock (including the North Fort) by building type served by fossil fuels in terms of heated floorspace, number of buildings, average floorspace by building type, and percent difference from Fort total floorspace.

The following are some specific notes concerning percentage differences from all buildings:

> Some of the concrete and wood barracks and motor pools are known to be no longer used but are still maintained as property. Dining hall facilities that are attached to barracks in the non-system areas were not identifiable separately from the barracks in terms of fuel use. These were included with barracks, thereby reducing the number of dining halls listed. Some of the newer office structures may be all electric and would therefore not be included in the tally.

Nine of the 15 identified building types account for over 90% of the heated square footage. Family housing comprises the largest share of floorspace, accounting for nearly 27% of the total, followed by barracks housing for unaccompanied personnel, accounting for nearly 21% of the total. Office/administration buildings make up the next largest share with almost 12% of the total, followed by New Madigan with over 9%, and warehouses, motor pools, and "other" with over 8% each.

2.1.3 Process Functions and Field Operations

Process functions at Fort Lewis were found to be primarily vehicle wash functions. Most of these activities were noted by base personnel to be field supported or operated using portable wash units. A portion of the steam supplied to one of the warehouse building areas is used for wash functions. In general, these activities were considered outside the scope of this assessment, and the total fuel consumption due to these activities is

TABLE 2.1. Building Stock Served by Fossil Fuel

Building Type	Heated Floorspace (ft^2)	Percentage of Total Heated Floorspace	Number of Buildings	Floorspace (ft^2)	Change From Fort Total Floorspace (%)
Residential	5,882,906	26.7	2,204[(a)]	1,678[(b)]	<1
Concrete Barracks	3,317,976	15.0	78	42,538	-5
Wood Barracks	1,309,439	5.9	276	4,744	-10
Office/ Administration	2,633,975	11.9	636	4,141	-9
Warehouse	1,908,328	8.7	140	13,631	-35
Motor Pool	1,791,642	8.1	199	9,003	-7
Hangar	366,005	1.7	8	45,751	0
Dining Halls	86,880	0.4	17	5,111	-30
Clubs	105,118	0.5	7	15,017	-6
Old Madigan	732,835	3.3	76	9,643	<1
New Madigan	2,000,000	9.1	1	2,000,000	0
Commissary	105,000	0.5	1	105,000	0
Computer Center	15,398	0.1	1	15,398	0
Miscellaneous (no. ft^2)[(c)]	NA	NA	5	NA	NA
Other	1,797,826	8.2	269	6,683	-15
Total	22,053,328		3,918		-7.8

(a) Contains total of 3505 living units.
(b) Average floorspace per living unit.
(c) The miscellaneous category consists of those buildings for which we have fuel bills but no square footage data.

relatively small. Field operations at Fort Lewis requiring fuel use are noted to be relatively small and erratic. As with process functions, these were outside the scope of this assessment.

2.1.4 Utility Service and Other Energy-Use Characterization

The utility and other energy-use site services present at Fort Lewis include eight primary steam and hot water distribution systems (with associated line losses), a sewer and water distribution system, streetlighting, and electrical distribution transformer (with line losses).

The eight steam and hot water supply systems at the Fort provide space heating and water heating to non-residential buildings located in areas around the airfield, hospital, and logistics area. The systems are as follows:

SYSTEM	AREA	TYPE	FUEL
3LC	Northwest Logistics	Steam	#6 Oil/Gas
5LC	Central Logistics	Steam	#6 Oil/Gas
6	Old Madigan Hospital Area	Steam	#6 Oil/Gas
7	Central Stadium, Theater, Gymnasiums	Steam	#2 Oil/Gas
9	North Section, East of Airfield	Water	#6 Oil/Gas
10	Central Section, East of Airfield	Water	#6 Oil
11	South Section, East of Airfield	Water	#6 Oil
14	Entire Section, West of Airfield	Water	#6 Oil/Gas

Losses associated with these distribution systems are characterized by two primary modes. The first is leakage of steam or hot water through faulty traps and connections, broken lines, and heat exchanger equipment in need of repair; the second comes in the form of thermal (conduction) losses throughout the system from uninsulated lines.

The shares of buildings and square footage served by district systems are 10% and 26%, respectively. Of the buildings served directly by fossil fuels (based on all heated structures), 33% are non-residential and account for 48% of the floorspace; the remaining 57% of buildings are residential and account for 26% of the floorspace.

Virtually all of the fossil fuel at the Fort is used for building heat and domestic hot water. Fuel forms used directly (combusted within the building boundary) are natural gas and fuel oil #2. Natural gas and fuel oil #6 are the primary fuels consumed to provide steam and hot water to buildings through the district systems.

Natural gas provides space heat for all of the housing areas, except a portion of Madigan, which uses fuel oil #2. In addition, water heat is provided by gas for two housing areas. Each of the buildings served by natural gas is metered separately, and the meter is read monthly by the natural gas company. Delivery records are maintained for fuel oil #2 provided to buildings served directly as well as for the eight central boilers.

In 1989, the price paid by Fort Lewis for natural gas from Washington Natural Gas ranged from $2.10 per MBtu for large interruptible accounts to $5.10 per MBtu for residential accounts. The average price paid for natural gas was $3.64 per MBtu. The prices paid for fuel oil were $6.55 per MBtu for fuel oil #6 and $7.42 per MBtu for fuel oil #2.

2.2 ENERGY CONSUMPTION BASELINE

The estimated baseline fossil-fuel energy consumption is provided by fuel type and end use, and by building type for buildings served directly by fossil fuels and those served by a district system.

Baseline energy consumption for non-system buildings is shown in Table 2.2. The estimated shares between natural gas and fuel oil #2 are about 60% and 40%, respectively. Five of the building types account for 90% of the direct natural gas consumption: residential housing (53%), motor pool (15%), "other" (12%), barracks (6%), and office/administration (4%). Four of the building types account for nearly 90% of the direct #2 fuel oil consumption: office/administration (34%), barracks (23%), "other" (17%), and motor pool (13%). It is estimated that nearly 84% of the fuel was used to provide space heat and 16% to provide water heat.

Baseline energy consumption for system buildings is shown in Table 2.3. The estimated shares by fuel type are 51% natural gas, 49% fuel oil #6, and less than 1% fuel oil #2,. Distribution losses were estimated to be approximately 39% of the total energy supplied to the eight central boilers. Of the energy supplied to the buildings (energy input to the boilers less distribution losses) in the form of natural gas, 95% was accounted for by five building types: concrete barracks (31%), motor pool (20%), warehouse (8%), Old Madigan (23%), and "other" (13%). It is estimated that all the fuel oil #2 was consumed by the "other" category. Approximately 92% of fuel oil #6 was consumed in five building types: concrete barracks (53%), motor pool (15%), office/administration (9%), hangar 8%, and other (7%). It is estimated that 69% of the fuel was used to provide space heat and 31% to provide water heat.

TABLE 2.2. Estimated Fossil-Fuel Baseline (MBtu)[a] by Building and End Use for All Non-Distribution System Facilities

Building Type	Total Gas (MBtu)	HVAC[b] Gas (MBtu)	DHW Gas (MBtu)	Total #2 Oil (MBtu)	HVAC #2 Oil (MBtu)	DHW #2 Oil (MBtu)	Total #6 Oil (MBtu)	HVAC #6 Oil (MBtu)	DHW #6 Oil (MBtu)	Total All Fuels (MBtu)	Percent of Total (%)
Residential	309,958	295,962	13,996	3,466	3,466	0	0	0	0	313,424	32.0
Barracks (Concrete)	31,732	19,648	12,084	33,423	20,695	12,727	0	0	0	65,154	6.65
Barracks (Wood)	2,989	1,825	1,164	83,608	51,049	32,558	0	0	0	86,597	8.84
Motor pool	85,501	81,696	3,805	42,751	40,848	1,902	0	0	0	128,252	13.10
Dining hall	0	0	0	2,584	1,253	1,331	0	0	0	2,584	0.26
Office/admin.	22,705	20,034	2,670	119,460	105,411	14,050	0	0	0	142,165	14.52
Warehouse	4,082	3,901	181	29,797	28,477	1,321	0	0	0	33,880	3.46
Hanger	16,317	15,591	726	576	551	26	0	0	0	16,894	1.73
Old Madigan	8,023	4,024	3,999	3,917	1,965	1,953	0	0	0	11,940	1.22
New Madigan	0	0	0	0	0	0	0	0	0	0	0.00
Clubs	12,200	5,918	6,282	1,660	805	855	0	0	0	13,860	1.42
Commissary	3,327	1,114	2,212	0	0	0	0	0	0	3,327	0.34
Others	69,902	49,917	19,985	73,412	52,424	20,988	0	0	0	143,314	14.64
Computer center	1,130	952	178	0	0	0	0	0	0	1,130	0.12
No. Sq ft	16,096	9,964	6,133	505	312	192	0	0	0	16,601	1.70
Non-System Total	583,962	510,547	73,414	395,161	307,257	87,903	0	0	0	979,122	100.00
Percent of Total	59.64	52.14	7.50	40.36	31.38	8.98	0.00	0.00	0.00	100.00	

(a) Million Btu.
(b) Heating, Ventilating, and Air Conditioning.

TABLE 2.3. Estimated Fossil-Fuel Baseline (MBtu)[a] by Building and End Use for All Distribution System Facilities

Building Type	Total Gas (MBtu)	HVAC[b] Gas (MBtu)	DHW Gas (MBtu)	Total #2 Oil (MBtu)	HVAC #2 Oil (MBtu)	DHW #2 Oil (MBtu)	Total #6 Oil (MBtu)	HVAC #6 Oil (MBtu)	DHW #6 Oil (MBtu)	Total All Fuels (MBtu)	Percent of Total (%)
Barracks (conc. w/ dh)	22,176	12,793	9,383	0	0	0	43,150	24,892	18,257	65,326	8.71
Barracks (conc. w/o dh)	44,932	25,920	19,011	0	0	0	82,942	47,848	35,094	127,873	17.06
Barracks (wood)	218	133	85	0	0	0	7	5	3	226	0.03
Motor Pool	42,933	40,640	2,293	0	0	0	35,242	33,360	1,882	78,175	10.43
Dining Hall	3,035	2,928	107	0	0	0	9,961	9,611	350	12,996	1.73
Office/Admin.	5,867	5,039	828	0	0	0	21,188	18,198	2,990	27,055	3.61
Warehouse	18,694	17,700	994	0	0	0	881	834	47	19,576	2.61
Hanger	68	65	4	0	0	0	19,955	18,889	1,065	20,023	2.67
Old Madigan	51,161	20,562	30,599	0	0	0	4,376	1,759	2,617	55,537	7.41
New Madigan	0	0	0	0	0	0	0	0	0	0	0.00
Clubs	1,482	566	916	0	0	0	151	58	93	1,633	0.22
Commissary	0	0	0	0	0	0	0	0	0	0	0.00
Others	29,129	19,136	9,993	827	543	284	16,540	10,866	5,675	46,496	6.20
Computer Center	15	13	2	0	0	0	4,334	3,721	613	4,349	0.58
Distribution Losses	159,668	105,734	53,934	272	179	93	130,443	92,912	37,531	290,383	38.74
All System Total	379,378	251.229	128,149	1,099	722	377	369,171	262,953	106,218	749,648	100.00
Percent of Total	50.61	33.51	17.09	0.15	0.10	0.05	49.25	35.08	14.17	100.00	

(a) Million Btu.
(b) Heating, Ventilating, and Air Conditioning.

Of the total fossil-fuel energy provided to all buildings, 57% is consumed within building boundaries, 27% is provided to buildings through the district systems, and 17% is in the form of distribution losses. Natural gas accounts for 56% of total fossil energy consumption, of which 60% is consumed within building boundaries and 40% by the district systems. Virtually 100% of fuel oil #2, which accounts for 23% of the total fossil energy consumption, is consumed within building boundaries. Fuel oil #6 accounts for 21% of total fossil energy use and is allocated 100% to the district systems. Several of the building types were larger consumers of fossil fuels, both directly and from the distribution system. These types are barracks (20% of total fossil-fuel use), residential (18% of the total), motor pool (12%), "other" (11%), and office/administration (10%). The five noted building types account for about 70% of the Fort's fossil energy consumption.

3.0 RESOURCE ASSESSMENT

This section describes the analysis approach taken to assess the fossil-fuel-based efficiency resource available at Fort Lewis and presents the findings. The findings are provided by facility sector and end use, fuel type, and implementation approach (efficiency conservation opportunities versus fuel-switching).

3.1 ANALYSIS APPROACH

The approach to assessing the fossil energy-efficiency resource potential consisted of identifying the range of measures that apply to the three building types and the thermal district systems: developing the costs and associated efficiency improvements for these measures; and calculating the life-cycle cost (LCC), net present value (NPV), and a value index (VI) for each measure (see Section 3.1.2). This section provides the list of energy conservation opportunities (ECOs) and fuel-switching measures that were considered and presents the NPV and VI measures that were developed.

Because of the restrictions currently placed on renovating/retrofitting "temporary" (wood-constructed) buildings in the North Fort area, the resource assessment excludes these buildings. These buildings are in the non-residential/non-system building sector and represent nearly 660 structures with over 2 million square feet. If, in the future, these buildings are retrofitted with energy-efficient technologies, the net fossil-fuel energy-use reduction would be increased by 31,000 MBtu with a corresponding increase in NPV of $5 million and an additional reduction of $300,000/year in the Fort's fossil-fuel energy bill (see Table S.2).

3.1.1 Efficiency Measures Considered

Sixty-one efficiency measures were identified as candidates for implementation at Fort Lewis. Consultation with Fort Lewis staff, energy-efficiency experts, and PNL staff screened the list to 35 that were analyzed for efficiency potential and cost-effectiveness. A listing of the measures considered is provided in this section; the reader is referred to the appendixes in this report for further discussion of the all the measures that were considered.

Building Envelope Measures

The current insulation level of the building envelope and the building age were major factors affecting implementing ECOs in this group. These ECOs affect space heating fuel use only:

- Insulate suspended ceilings of non-residential buildings >20 years old with batt-type, non-rigid insulation from R-11 to R-19.
- Insulate attic ceilings of wood frame buildings (residential and wooden barracks) with batt-type, non-rigid insulation from R-11 to R-19.
- Blow-in wall insulation for wooden frame buildings from a base R-11 insulation value (supplied by solid foam insulation) to R-19.
- Insulate interior brick surface walls for a portion of the concrete barracks.
- Insulate perimeter of slab-on-grade below surface to an R-7.7 level for residential housing.
- Insulate floor above crawl space by hanging insulation from the current R-3 level to R-11 on 75% of the wooden barracks.
- Install storm windows as a retrofit on 30% of the windows in concrete barracks.
- Caulk and weatherstrip windows and leaks to reduce infiltration on buildings that serve as residences (residential housing and wooden and concrete barracks).

Building Auxiliary Heating Measures

These ECOs affect space heating fuel use only:

- Install infrared heaters for radiation heating of limited spaces within large areas including hangars, motor pools, and warehouse building types.
- Install programmable setback thermostat controls.

Water Heating Measures

These ECOs affect domestic hot water fuel use only:

- Install low-flow shower heads in the remaining available locations.
- Insulate DHW pipes in residential housing and wooden and concrete barracks.
- Install specially lined (non-corrosive) gas water heaters. This ECO is part of a fuel-switching option outlined below.

Boiler Measures

Boiler capacity (MBtu/hr), age, and fuel type were the main factors affecting implementation of ECOs in this group. Typically, the Fort Lewis main plant boilers for central steam distribution ranged from 5 to 60 MBtu/hr. The boilers dedicated to a building unit typically ranged in size from 0.2 to 1 MBtu/hr. These ECOs affected space-heating fuel use only:

- Install a combustion air preheater to reduce energy losses in the boiler flue. Applicable to capacities >40 MBtu/hr.
- Install feedwater economizers in the boiler flue to preheat condensate return and make-up water. Applicable to capacities >3 MBtu/hr.
- Install air atomizing burners and low excess air (LEA) burners for oil burning boilers to increase combustion efficiency. Applicable to all boiler sizes; increased efficiency is related to the age of the retrofit boiler.
- Perform boiler tune-up by optimizing air-to-fuel ratios. Applicable to all boiler sizes and should be performed once a year.
- Install flue gas analyzers to assist in maintaining optimal boiler efficiency. Applicable to capacities >10 MBtu/hr.
- Install automatic electric dampers to reduce standby loss when the boiler is not in use. Applicable to all boiler sizes; most effective with boilers that cycle diurnally.
- Install new and more efficient oil- or gas-burning conventional boilers. Applicable to capacities <25 MBtu/hr; it is thought the high capital costs associated with capacities greater than this would warrant a more detailed study by each individual boiler case. This ECO is part of a fuel-switching option outlined below.

- Install new gas pulse or condensing boilers to replace older, less efficient oil boilers. Applicable to capacities <1 MBtu/hr. This ECO is part of a fuel-switching option outlined below.

- Install fire-tube turbulators in fire-tube boilers to improve overall combustion efficiency. Applicable to boilers from 1 to 20 MBtu/hr that are older than 15 years.

- Replace manual boiler blow-down system with a continuous boiler blow-down system with heat recovery capability. Applicable to capacities >6 MBtu/hr.

- Install oxygen trim control to maintain low excess air levels. Applicable to all boiler sizes.

- Provide maintenance of existing feedwater economizers found on larger (>3 MBtu/hr) boilers.

<u>District Thermal Distribution Measures</u>

The steam and fuel line diameters and current insulation levels, as well as the capacity and age of the main plant boilers and thermal distribution lines, were important factors affecting the level of implementation of the ECOs in this category. These ECOs affect space-heating fuel use only:

- Repair or replace defective steam traps.

- Insulate buried pipe of main distribution lines. This assessment considers insulating only a small portion (15%) of the buried distribution lines because of accessibility and locating problems.

- Insulate above-ground pipe of main distribution lines. This would largely affect distribution line above ground not found in the building's interior, where thermal losses could be a source of space heating.

- Insulate hot fuel-oil pipes leading from the heater to the burner within the boiler.

- Locate steam mass losses in buried steam distribution lines with infrared (IR) technology and repair the leaks.

- Install water-to-water heat exchangers for heat recovery in dining hall facilities.

- Insulate hot water storage tanks.

Fuel-Switching Opportunities

Fuel-switching is another area of conservation potential. While efficiency improvements are possible with new technologies (e.g., the specially lined, non-corrosive water heaters are more efficient than the conventional electric water heaters), fuel-switching can allow the site to take advantage of more economical fuel choices. Fuel-switching opportunities investigated include:

- Switch old oil boiler to a conventional gas boiler.
- Switch old oil boiler to a gas pulse combustion boiler.
- Switch conventional electric water heater to a specially lined gas water heater with the following two scenarios:
  - replace 100% of existing conventional water heaters with the specially lined gas water heaters all at once
  - replace 20% of the existing conventional water heaters with the specially lined gas water heaters each year. Information from Fort Lewis staff indicates that the life expectancy of the existing water heaters is less than five years due to tank corrosion caused by carbonic acid.
- Replace oil-fired infrared heaters with gas-fired units in non-residential system buildings.

3.1.2 Value Index (VI) Measures

A VI is used a the measure to prioritize the cost-effective fossil-fuel ECOs. The VI is the ratio of the NPV of an ECO to its installed cost. The VI is analogous to a savings to investment ratio, but uses life-cycle-discounted measure of savings. A VI greater than 0 is considered a viable ECO, and the greater the VI, the more attractive the ECO.

3.2 RESOURCE POTENTIAL BY FACILITY SECTOR AND END USE

The 35 measures considered were applied to the three building sectors (residential, non-residential non-system, and non-residential system) and the district thermal system and analyzed by type of fuel consumed. This resulted in 110 cases in which measures were analyzed and provided 72 with positive

TABLE 3.1. Energy-Efficiency and Fuel-Switching Measures Having Positive Net Present Values, by Sector

	Energy-Use Reduction (MBtu)										
	Natural Gas	Fuel Oil #2	Fuel Oil #6	Elec-tricity	Total	Initial Cap. Cost (1991 $)	Present Value of O&M Costs (1991 $)	Annual Energy Savings (MBtu)	Value of Annual Energy Savings (1991 $)	NPV of Strategy (1991 $)	Value Index
<u>District System</u>											
District Thermal Distrib.											
Ins buried pipe-main dist line	0	9	0	0	9	202	0	9	69	1,020	5.06
Ins above grnd dist pipe	0	16	0	0	16	80	0	16	118	2,006	25.06
Water-to-water heat exchanger	2,262	0	0	0	2,262	5,255	0	2,262	4,750	109,725	20.88
Ins Hot Water Storage Tanks	0	16	0	0	16	177	0	16	116	1,871	10.57
Minimize Losses in Steam Lines	0	0	19,580	0	19,580	103,976	0	19,580	128,246	2,956,654	28.44
Minimize Losses in Steam Lines	0	4	0	0	4	35	0	4	28	454	13.12
Insulate Hot Fuel Oil Pipes	0	0	4,186	0	4,186	37,715	0	4,186	27,418	616,612	16.35
Minimize Losses in Steam Lines	5,098	0	0	0	5,098	31,541	0	5,098	10,705	198,346	6.29
Ins Hot Water Storage Tanks	0	0	10,366	0	10,366	117,089	0	10,366	67,899	1,503,337	12.84
Ins above grnd dist pipe	13,265	0	0	0	13,265	44,056	0	13,265	27,856	474,328	10.77
Ins Hot Water Storage Tanks	6,754	0	0	0	6,754	76,292	0	6,754	14,184	236,274	3.10
Ins buried pipe-main dist line	4,019	0	0	0	4,019	86,807	0	4,019	8,440	99,177	1.14
Ins buried pipe-main dist line	0	0	6,167	0	6,167	133,221	0	6,167	40,397	830,864	6.24
Water-to-water heat exchanger	0	0	4,903	0	4,903	36,323	0	4,903	32,115	730,103	20.10
Ins above grnd dist pipe	0	0	30,469	0	30,469	94,952	0	30,469	199,572	4,667,884	49.16
Subtotal	31,398	45	75,671	0	107,113	767,721	0	107,113	561,912	12,428,655	16.19
<u>Non Residential/Non System</u>											
Bldg. Aux. Heating											
Infrared heaters	12,083	0	0	0	12,083	68,414	0	12,083	38,665	563,381	8.23
Bldg. Envelope											
Ins floor above crawl space	0	14,492	0	0	14,492	220,577	0	14,492	107,530	1,669,923	7.57
Ins floor above crawl space	566	0	0	0	566	8,609	0	566	1,810	20,141	2.34
Ins int brick surface walls	0	88	0	0	88	9,446	0	88	655	2,064	0.22
Insulate attic ceilings	0	2,174	0	0	2,174	165,432	0	2,174	16,130	118,152	0.71
Insulate suspended ceilings	0	1,010	0	0	1,010	56,628	0	1,010	7,494	75,131	1.33
Boilers											
Automatic electric dampers	7,496	0	0	0	7,496	46,410	0	7,496	23,987	334,607	7.21
Feedwater economizers	102	0	0	0	102	3,639	0	102	326	1,546	0.42
Fire-tube turbulators	721	0	0	0	721	1,176	0	721	2,307	35,472	30.16
Ins above grnd dist pipe	0	14,213	0	0	14,213	71,604	0	14,213	105,463	1,782,553	24.89
Ins above grnd dist pipe	6,911	0	0	0	6,911	34,815	0	6,911	22,114	316,456	9.09
Ins Hot Water Storage Tanks	6,816	0	0	0	6,816	76,984	0	6,816	21,813	269,492	3.50
Ins Hot Water Storage Tanks	0	14,018	0	0	14,018	158,330	0	14,018	104,017	1,670,286	10.55
Water-to-water heat exchanger	0	106	0	0	106	4,506	0	106	784	9,285	2.06

TABLE 3.1. (contd)

	Energy-Use Reduction (MBtu): Natural Gas	Fuel Oil #2	Fuel Oil #6	Electricity	Total	Initial Cap. Cost (1991 $)	Present Value of O&M Costs (1991 $)	Annual Energy Savings (MBtu)	Value of Annual Energy Savings (1991 $)	NPV of Strategy (1991 $)	Value Index
Fuel Switch											
Elec to gas DHW - CR	-14,587	0	0	12,679	-1,908	282,757	-231,686	-1,908	47,400	344,164	1.22
Infrared heaters	-43,358	51,000	0	0	7,642	81,406	0	7,642	239,459	4,519,407	55.52
Oil to conv gas boiler	-49,060	51,827	0	0	2,768	1,820,371	0	2,768	227,323	2,593,182	1.42
Water Heating											
Ins Service Hot Water Pipes	0	657	0	0	657	10,512	0	657	4,878	75,249	7.16
Ins Service Hot Water Pipes	112	0	0	0	112	1,794	0	112	359	3,910	2.18
Low Flow Shower Heads	0	1,564	0	0	1,564	6,890	0	1,564	11,604	197,124	28.61
Low Flow Shower Heads	318	0	0	0	318	885	0	318	1,017	15,265	17.24
Subtotal	-71,880	151,150	0	12,679	91,948	3,131,186	-231,686	91,948	985,129	14,616,789	4.67
Non Residential/System											
Bldg. Aux. Heating											
Infrared heaters	8,760	0	0	0	8,760	55,533	0	8,760	18,396	245,074	4.41
Bldg. Envelope											
Ins int brick surface walls	0	0	272	0	272	29,195	0	272	1,781	13,319	0.46
Install storm windows	0	0	194	0	194	26,236	0	194	1,268	4,024	0.15
Insulate suspended ceilings	0	0	821	0	821	46,360	0	821	5,375	81,917	1.77
Boilers											
Air atom. burners/LEA burners	0	0	9,239	0	9,239	901,444	0	9,239	60,518	542,844	0.60
Auto blowdown w/ heat recovery	5,470	0	0	0	5,470	200,928	0	5,470	11,487	23,944	0.12
Auto blowdown w/ heat recovery	0	0	5,544	0	5,544	218,914	0	5,544	36,311	647,659	2.96
Automatic electric dampers	6,480	0	0	0	6,480	4,514	0	6,480	13,608	270,771	59.98
Automatic electric dampers	0	22	0	0	22	47	0	22	163	2,835	59.95
Automatic electric dampers	0	0	4,184	0	4,184	5,618	0	4,184	27,407	648,447	115.41
Boiler tuneup	0	22	0	0	22	0	1,368	22	163	1,515	(a)
Feedwater economizers	2,369	0	0	0	2,369	48,397	0	2,369	4,975	49,858	1.03
Feedwater economizers	0	0	2,310	0	2,310	90,991	0	2,310	15,130	270,081	2.97
Feedwater economizers	0	7	0	0	7	336	0	7	51	565	1.68
Flue gas analyzer	9,117	0	0	0	9,117	132,595	0	9,117	19,146	242,214	1.83
Flue gas analyzer	0	0	9,239	0	9,239	93,373	0	9,239	60,518	1,350,916	14.47
Maintenance of economizers	2,369	0	0	0	2,369	79,573	0	2,369	4,974	18,661	0.23
Maintenance of economizers	0	7	0	0	7	336	0	7	51	565	1.68
Maintenance of economizers	0	0	2,310	0	2,310	90,991	0	2,310	15,130	270,081	2.97
Oxygen trim control	0	0	4,805	0	4,805	130,722	179,072	4,805	31,470	441,236	3.38

TABLE 3.1. (contd)

	Energy-Use Reduction (MBtu)										
	Natural Gas	Fuel Oil #2	Fuel Oil #6	Elec-tricity	Total	Initial Cap. Cost (1991 $)	Present Value of O&M Costs (1991 $)	Annual Energy Savings (MBtu)	Value of Annual Energy Savings (1991 $)	NPV of Strategy (1991 $)	Value Index
Fuel Switch											
Infrared heaters	-45,121	0	53,083	0	7,962	68,647	0	7,962	252,940	7,023,987	102.32
Water Heating											
Ins Service Hot Water Pipes	0	0	160	0	160	2,559	0	160	1,045	22,386	8.75
Ins Service Hot Water Pipes	122	0	0	0	122	1,953	0	122	257	2,729	1.40
Low Flow Shower Heads	0	0	2,494	0	2,494	5,986	0	2,494	16,337	383,896	64.13
Low Flow Shower Heads	1,730	0	0	0	1,730	4,152	0	1,730	3,633	68,676	16.54
Subtotal	-8,704	58	94,654	0	86,008	2,239,400	180,440	86,008	602,134	12,628,201	5.64
Residential											
Bldg. Aux. Heating											
Setback Thermostat Controls	19,374	0	0	0	19,374	218,155	0	19,374	98,809	1,297,193	5.95
Bldg. Envelope											
Ins perimeter of slab	586	0	0	0	586	5,901	0	586	2,988	39,930	6.77
Ins perimeter of slab	0	6	0	0	6	61	0	6	45	676	11.13
Insulate attic ceilings	13,346	0	0	0	13,346	507,808	0	13,346	68,063	536,320	1.06
Water Heating											
Ins Service Hot Water Pipes	144	0	0	0	144	2,315	0	144	735	8,962	3.87
Low Flow Shower Heads	558	0	0	0	558	3,349	0	558	2,845	40,290	12.03
Subtotal	34,008	6	0	0	34,014	737,588	0	34,014	173,485	1,923,070	2.61
TOTAL	-15,179	151,258	170,325	12,679	319,084	6,875,895	-51,246	319,084	2,322,660	41,596,716	6.05

(a) Value Index not defined, because capital cost is zero.

NPVs. Of the 72, five were dropped from consideration due to competing measures that had higher NPVs. The analysis results for all 110 cases are provided in the appendixes.

The remaining 67 measures are displayed in Table 3.1 with their estimated initial capital cost, present value of operation and maintenance costs, annual energy savings, value of annual energy savings, NPV, and VI. These are sorted by application to each of the four sectors--district system, non-residential non-system buildings, non-residential system buildings, and residential buildings.

The shares of efficiency potential and NPV by sectors are as follows:

Sector	Energy-Use Reduction, %	NPV, %
District System	34	30
Non-Residential/Non-System	28	35
Non-Residential/System	27	30
Residential	11	5

The highest efficiency potential and NPV are in the non-residential non-system building stock, followed by actions in the district system and non-residential system buildings. Five actions with the highest value index are in the non-residential system buildings; although the energy-use reductions associated with these measures are relatively small, the return is high, which suggests these may be good initial investment areas.

3.3 RESOURCE POTENTIAL BY ENERGY SOURCE

Excluding fuel-switching opportunities, approximately 303,000 MBtu of annual savings are available. Of this, about 44% is in the form of natural gas, 36% in fuel oil #6, and 20% in fuel oil #2. The most cost-effective actions are in both types of fuel oil.

When taking fuel-switching opportunities (to natural gas) into account, the cost-effective energy-use reduction potential increases to nearly 319,000 MBtu annually. Significant additional reductions in fuel oil #2 are achieved with added reductions in fuel oil #6 and some electricity. These reductions are largely offset by increases in natural gas consumption. In net, natural gas use increases by over 15,000 MBtu. The most cost-effective fuel-switching actions are from #6 oil to gas-fired infrared heaters in non-residential system buildings and from electric to gas hot water heaters in non-residential non-system buildings.

3.4 DISCUSSION

The total cost-effective fossil-fuel efficiency resource at Fort Lewis (319,000 MBtu) is a reduction of approximately 18% of all the fossil fuel consumed in 1989. Acquiring all the cost-effective resource would be an investment with an estimated NPV of approximately $41.6 million. The annual fuel expenditure savings, evaluated at 1991 fuel prices, would be over $2.3 million.

Table 3.2 summarizes the cost-effective efficiency resource by end-use sector and fuel type. In the context of this discussion, the cost-effective resource includes all energy conservation investments that have a positive NPV. This table provides the energy use reduction, new load due to fuel-switching, net energy reduction, capital cost, value of annual energy savings, and associated NPV.

The non-residential non-system building sector has the greatest efficiency potential, followed by actions in the district system and non-residential system. As a whole, improvements to the district system show the quickest return, followed by actions in the non-residential non-system, non-residential system and residential buildings sectors.

In the tabulation of the 67 cost-effective applications of the 35 measures analyzed, 51 accounted for 99% of the energy-use reductions. Of these, 11 had energy reduction potential greater than 10,000 MBtu and accounted for 55% of the reduction, 14 had potential greater than 5,000 and less than 10,000 MBtu and accounted for an additional 30%, and 16 had potential greater than 1,000 and less than 5,000 MBtu, accounting for 14% of the reduction.

TABLE 3.2. Annual Cost-Effective Fossil-Fuel Efficiency Resource by Sector and Fuel Type

	Energy-Use Reduction (MBtu)	New Load (MBtu)	Net Energy-Use Reduction (MBtu)	Initial Capital Cost (1991 $)	Value of Annual Energy Savings (1991 $)	NPV of Strategy (1991 $)
By Sector (including fuel-switching)						
District System	107,113	0	107,113	767,721	561,912	12,428,655
Non-Residential/Non-System	198,953	107,005	91,948	3,131,186	985,129	14,616,789
Non-Residential/System	131,129	45,121	86,008	2,239,400	602,134	12,628,201
Residential	34,014	0	34,014	737,588	173,485	1,923,070
TOTAL	471,210	152,126	319,084	6,875,895	2,322,660	41,596,716
By Fuel						
Fuel Oil #2	48,430	0	48,430	705,199	359,189	5,609,758
Fuel Oil #6	117,242	0	117,242	2,165,664	767,936	15,982,261
Natural Gas	136,947	0	136,947	1,751,850	428,251	5,522,441
Fuel Switching (elec to gas)	12,679	14,587	-1,908	282,757	47,400	344,164
Fuel Switching (#2 to gas)	102,828	92,418	10,410	1,901,778	466,782	7,112,589
Fuel Switching (#6 to gas)	53,083	45,121	7,962	68,647	252,940	7,023,987
TOTAL	471,210	152,126	319,084	6,875,895	2,322,497	41,595,201

In the absence of fuel-switching actions, about 303,000 MBtu of efficiency potential exists, primarily in the form of natural gas, followed by fuel oils #6 and #2. The cost to acquire this potential is estimated to be about $4.6 million, which is about 65% of the cost to implement all cost-effective measures. The annual energy savings are estimated at about $1.6 million, with an NPV of about $27 million.

Implementing fuel-switching actions results in an additional savings of 16,000 MBtu. In this case, natural gas use increases, and the largest decrease in consumption is in the form of fuel oil #2, followed by fuel oil #6 and electricity. The cost to obtain the additional savings is about $2.3 million, which provides annual cost reductions of about $767,000, with an NPV of about $14.6 million.

4.0 SUMMARY AND RECOMMENDATIONS

A significant cost-effective potential is estimated to exist for reducing fossil-fuel consumption at the Fort Lewis Army installation. Sixty-seven investment actions were determined to have a positive net present value (NPV); four of these involved switching from fuel oil and electricity to natural gas, and the remainder involved efficiency improvements. Implementing these actions would reduce fossil-fuel use by an estimated 319,000 MBtu annually, reduce the annual fuel bill by about $2.3 million, and have an NPV of nearly $41.6 million. This would provide an 18% decrease in annual fossil energy use at the Fort and reduce the annual fossil-fuel energy bill by 31%.

The non-residential non-system building sector has the greatest efficiency potential, followed by actions in the district system and non-residential system. As a whole, improvements to the district system show the highest value index, followed by actions in the non-residential non-system, non-residential system, and residential buildings sectors.

Of the 67 cost-effective actions, 51 accounted for 99% of the energy-use reductions. Of these, 11 had energy reduction potential greater than 10,000 MBtu and accounted for 55% of the reduction; 14 had potential greater than 5,000 and less than 10,000 MBtu and accounted for an additional 30%; and 16 had potential greater than 1,000 and less than 5,000 MBtu and accounted for 14% of the reduction.

A suggested strategy to pursue implementation of these actions consists of the following:

- Fund the most cost-effective options (highest value index [VI]) out of operation and maintenance funds, freeing up budget resources to invest in the higher cost actions.
- Seek cofunding from the natural gas utility and/or funding through a performance contract to implement the fuel-switching measures.
- Develop budget request proposals for additional funds to implement higher cost measures.

This assessment is a first cut at estimating the fossil-fuel energy potential at the Fort. As such, the results should be highly useful in identifying, prioritizing, and implementing future energy-efficiency improvements. The results should not be used to draw conclusions regarding the cost-effectiveness about marginal actions, except that such actions require more detailed analysis.

5.0 SOURCES AND REFERENCES

Data sources used to characterize the baseline and fossil-fuel energy efficiency resource include databases maintained by the Fort, energy studies conducted previously for the Fort, and information available from other sources. These sources are described in this section.

5.1 DATABASES

Building/Facility Database - Base Format (dBASE File)

The dBASE file provided by Fort Lewis contains information on 3399 non-family housing structures located on the main post, including all permanent and temporary buildings and nonbuildings (e.g., sheds and shade covers, which are typically unconditioned). Virtually all of the buildings are a part of the regular Army and civilian contingent. A few (10 to 20) are a part of the Army Reserve function. Not included in this database are family housing units.

The database contains these five columns of information for each structure:

- building number
- building use description by original function
- number of floors - Those with "0" floors are meant to be primarily nonbuilding structures (e.g., boat ramps, shade covers, latrines, other similar unconditioned items). Some miscoding has occurred (e.g., "fire station" is "0," while several "overhead covers" are "1").
- "official" square footage of structure - This includes conditioned and unconditioned areas of structure and *may* include external areas (e.g., carports, shade roofs). Again, some miscoding is present in the form of enclosed structures with a "0" area.
- code indicating current use of structure - This is a five-digit category code (see Building Type Coding List, which follows).

Building Type Coding List (Paper Copy)

This list contains three-digit category codes used by the Army to categorize all buildings and facilities by their type (e.g., hangar, barracks) or area of use (e.g., airfield, shipyard).

Natural Gas Meter Reading Databases (dBASE File)

These files contain gas monthly consumption values in therms for each building on the post that was supplied with natural gas in fiscal years 1989 and 1990. Each file contains 11 input fields. The fields found useful for this assessment included a facility or building number and the therm delivery amounts for each month in 1989. One of the files included all of the gas-use data for the interruptable-rate facilities.

Fuel Oil Delivery Databases (dBASE File)

These files contain fuel oil (#2 and #6) delivery values for each tank in gallons. In most cases, one tank existed for each building supplied with oil. A total of 14 fields existed in the files; those used in this assessment included building number, gallons delivered, delivery date, and contract number. The contract number was useful in separating the #2 and #6 oil deliveries.

Fuel Oil Tank List Database (dBASE File)

This database provides information on the number and size of tanks currently used at each building.

Building/Facility Database (IFS) (Paper Copy)

This printout contains information on the breakdown of housing areas (e.g., size, number of units, age, location, construction type). It also appears to contain the same information on all other buildings on the post. No electronic copy was available at the time. This database appears to be the best source for the wide variety of data needed on building stock throughout the post. It is, however, not of practical use unless available in electronic format.

Real Property Housing List (Paper Copy)

This document includes a breakdown of single-family residential housing by area and quantity. It provides information not available elsewhere.

Energy-Use Spreadsheet (Lotus 1-2-3)

This spreadsheet presents various compilations of energy use for the post from 1986 to 1989. It includes monthly energy usage for electricity, natural gas, and fuel oils #2 and #6. The usage is displayed according to user: primary post, housing, and National Guard.

Post Maps (Paper Copy)

One set of maps includes building numbers for all identifiable buildings on the post. A second site map was color-coded during a site visit to identify groups of buildings and facilities served by each of the primary thermal distribution systems.

Computer-Aided Design (CAD) Drawings of Representative Post Buildings (Paper Copy)

The post CAD drawings provided no connected load, construction type, or occupancy information. Printouts of the CAD layouts were available for use in additional data gathering by walk-through audits. Data about the type, capacity, and condition of various fossil fuel equipment at the post were recorded on these drawings and used as reference information.

Washington Natural Gas Rate Schedules (11-1-90 Paper Copy)

Details for all of the gas rates used by Fort Lewis are included in this set of schedules. Also included with this form is a listing of those buildings on base supplied by various rates and a synopsis of the average and total gas costs per rate for the current fiscal year (1991).

5.2 FORT LEWIS ENERGY STUDIES

Energy Resources Management Plan 1987

The Resources Management Plan completed in January 1987 includes economic analyses of various building conservation projects involving insulation, infiltration, controls, reduced water flows, lighting, and storm windows. This study considered only non-family housing buildings on the post. Reevaluations of other Fort-wide energy projects are also included. Packaged projects that include floor, ceiling, and wall insulation, as well as infiltration sealing, controls, and other measures, are estimated to save over $3 million at a simple payback of less than five years. The report evaluated the consolidation of two central distribution plants and a waste incinerator. The distribution plant consolidation is already in progress. The feasibility of an emergency management control system (EMCS) for the post was studied and found to be practical in only the North Fort area. The report provides only minimal information on the building stock on the post.

Fort Lewis Energy Savings Opportunity Survey. January 1987. Bouillon Christofferson and Schairer Consulting Engineers, Seattle, Washington.

In this two-volume report with appendixes, potential energy conservation opportunities (ECOs) in the building stock are examined and other ECOs studied previously are reviewed. For the building stock, 91 buildings were surveyed to estimate the energy conservation potential in approximately 1400 buildings on the post from a list of 49 energy conservation measures.

Energy Survey of Army Dining Facilities at Fort Lewis, Washington. July 31, 1986. United Industries Corporation, Bellevue, Washington (DACA 67-85-C-0085, Report #8601, Prefinal Report).

This 1986 survey reports on an energy audit and analysis of 38 dining facilities on the post to identify retrofit and operation opportunities for improving energy efficiency.

Energy Surveys of Army Boiler Plants, Energy Engineering Analysis Program (EEAP) at Fort Lewis, Washington. October 1988. EMC Engineers, Inc., Eugene, Oregon (Narrative Report, Book 1 of 2).

This study included detailed boiler information for a large subset of the many water and steam boilers at the post. It included sizing, efficiency, fuel, firing rate, and other useful information.

5.3 SECONDARY INFORMATION

Secondary sources of information included the following documents:

Conservation Resources Supply Document. 1990. Bonneville Power Administration, Portland, Oregon.

This report provides technical documentation of information used to develop the Bonneville Draft 1990 Conservation Supply Document.

Technical Appendix to Conservation Supply for the 1990 Power Plan. 1989. Northwest Power Planning Council.

This report provides technical documentation of information used to develop the Northwest Power Planning Council estimate of electric energy efficiency resources in the Pacific Northwest.

Description of Electric Energy Use in Single-Family Residences in the Pacific Northwest. July 1989. DOE/BP-13795-21, Bonneville Power Administration, Portland, Oregon.

This report provides summary information on end-use metered consumption of electricity in 499 residences in the Pacific Northwest during the period September 1984 through May 1988.

Description of Electric Energy Use in Commercial Buildings in the Pacific Northwest. December 1989. DOE/BP-13795-22, Bonneville Power Administration, Portland, Oregon.

This report provides summary information on end-use metered consumption of electricity in nearly 100 commercial buildings in the Pacific Northwest during the period September 1984 through October 1988.

Prototype Dining Hall Energy Efficiency Study. June 1988. PNL-6610, Pacific Northwest Laboratory, Richland, Washington.

This report provides information on end-use energy consumption for a prototypical Air Force dining hall and gives recommendations on cost-effective energy conservation options.

Commercial Buildings Consumption and Expenditures 1986. May 1989. DOE/EIA-0318(86), Energy Information Administration, Washington, D.C.

This report gives survey results and national and regional estimates of energy consumption and expenditures for commercial buildings in 1986.

Federal Register. Vol 55, No. 224. Tuesday, November 20, 1990.

Lippiatt, B. C., and R. T. Ruegg. October 1990. "Energy Prices and Discount Factors for Life-Cycle Cost Analysis 1991: Annual Supplement to NIST Handbook 135 and NBS Special Publication 709." NISTIR-85-3273-5, U.S. Department of Commerce, Gaithersburg, Maryland.

5.4 ENERGY CONSERVATION OPTIONS

In addition to the resources described in Sections 5.1 through 5.3, the following sources were useful in developing the list of energy conservation options (ECOs) that were considered for implementation at Fort Lewis.

Architect's and Engineer's Guide to Energy Conservation in Existing Buildings, Volume 1 - Energy Use Assessment and Simulation Methods. April 1990. DOE/RL/01830P-H4, DOE Field Office, Richland, Washington.

Architect's and Engineer's Guide to Energy Conservation in Existing Buildings, Volume 2 - Energy Conservation Opportunities. April 1990. DOE/RL/01830P-H4, DOE Field Office, Richland, Washington.

Kirsch, F. W. January 1982. Directory of Industrial Energy Conservation Opportunities - DIECO. University City Science Center, Industrial Technology and Energy Management. (Originally prepared under the Energy Analysis and Diagnostic Center Program (EADC), revised in November 1988).

Parker, S. A. 1991. "Have You Looked in the Boiler Room Lately?" Energy Engineering, 88(1):6-25.

Technical Energy Evaluation - Andrews AFB Commissary. February 27, 1987. Conservation Design Associates, Inc., Reston, Virginia.

Technical Energy Evaluation - Griffiss AFB Commissary. March 5, 1987. Conservation Design Associates, Inc., Reston, Virginia.

APPENDIX A

BASELINE DETAIL

APPENDIX A

BASELINE DETAIL

A.1 PHYSICAL CHARACTERISTICS

A.1.1 Site Profile

Fort Lewis is a U.S. Army Forces Command (FORSCOM) installation providing headquarters for the I Corps and 9th Infantry Division. The primary mission of the Fort is to provide training and combat readiness for assigned units and other military and reserve forces. The Madigan Army Medical Center, a major tenant, provides patient care, medical research and medical training to Army and other personnel. Fort Lewis also has responsibility for three sub-installations that support the training and readiness missions.

Fort Lewis proper is located on nearly 87,000 acres of property to the south of the City of Tacoma, Washington. The three sub-installations account for over 260,000 acres located in other parts of Washington State.

The climate is coastal in nature with average summer (July) temperatures ranging from a low of 49°F to a high of 77°F and average winter (January) temperatures ranging from 31 to 44°F, providing for average heating and cooling degree days of 5709 and 94, respectively. Annual precipitation averages 51 inches per year, and the average windspeed is about 7 mph.

Fort Lewis houses approximately 25,000 full-time residents and has a daytime population of approximately 35,000 persons. The stock of nearly 4,500 buildings comprises approximately 24 million square feet of floorspace.

A.1.2 Building and Facility Profile

Site Facility and Housing Characterization

The building database provided by Fort Lewis contained information on all Fort non-residential facilities. This includes all non-building facilities (e.g., sheds, bus stop shelters, flagpoles, walkways). The database is generally set up to use a "number of floors" value of "0" to identify non-building type structures. Therefore, the original sorts (by three-digit code) of the database were based on all buildings with one or more floors. This led to the omission of many obvious conditioned buildings (apparently miscoded with "0" floor). In addition, many facilities are coded under specific operational categories (e.g., "airfield" or "maintenance") rather than categories that closely match the chosen prototypes. For these reasons, the remainder of the database was manually searched, and additional five-digit categories were identified as fitting with the prototypes. These buildings, as well as any obvious conditioned facilities with "0" floor codings, were added to the original database sort totals. Still remaining was a small subset of buildings with one or more floors but "0" square footage. For these buildings, the square footage was obtained from Fort personnel and added to the appropriate category totals. For residential buildings not included in the above database, different data sources were used. The Real Property Housing List and Resources Management Plan were used to arrive at total unit numbers for each housing area, as well as associated building numbers. The Building/Facility Database - (IFS) type contained square footage values for each unit and an indication of building age and type (e.g., single, duplex). Because these data existed only in paper form, they were manually transferred from the printout to arrive at square footage totals for each type and vintage (year of construction) of housing units.

The building type values derived from the various sources are summarized in Table A.1.

Of the total estimated building stock at Fort Lewis, 4457 buildings with 23.9 million square feet of floorspace, fossil-fuel delivery and meter records show that 3918 of these were served by fossil fuels. The differences are understood to be all electric buildings, utility facilities without fossil-fuel service, buildings not on line in 1989, or facilities closed or not served by fossil fuel in 1989.

TABLE A.1. Fort Lewis Building Stock Summary

Building Type	Total Area (ft^2)	Building Count	Average Size/Unit (ft^2)
Single Residence[a]	3,207,801	1,811	1,771
Multiple Residence[a]	2,675,095	394	1,579[b]
TOTAL	5,882,896	2,205	NA
Barracks Three-story concrete[c]	3,209,566	79	40,627
Barracks Two-story wood[d]	1,461,532	29	15,022
Motor Pool[e]	1,926,594	252	7,645
Dining Hall[f]	124,377	24	5,182
Office/Administration[g]	2,892,262	715	4,045
Warehouse[h]	2,933,673	446	6,577
Old Madigan[i]	736,651	79	9,324
Hangar	333,005	8	45,750
New Madigan Hospital (approximate)	2,000,000	1	2,000,000
Commissary	105,000	1	105,000
Computer Center	15,398	1	15,398
Simulator(s)	54,200	2	27,100
Club(s)[j]	112,168	8	14,021
Other	2,116,933	345[k]	6,136[k]
FORT LEWIS GRAND TOTAL	23,937,346[k]	4,457[k]	NA

(a) The vintage of all the residential units ranges from the early 1940s to the 1980s; most were constructed in the 1950s to 1960s.

(b) These 394 multiple residence buildings contain a total of 1694 units and vary from duplexes to eight-unit complexes.

(c) Includes all three-story facilities in Army code groups 721, 724 (none), and 725 (none): unaccompanied enlisted personnel barracks-type structures with or without dining areas and associated latrine and other facilities (construction type not identified in database, but virtually all three-story units are known to be concrete/brick/masonry).

(d) Includes all two-story or less facilities in Army code groups 721, 74032, 724 (none), and 725 (none): unaccompanied enlisted personnel barracks-type structures with or without dining areas and associated latrine and other facilities (construction type not identified in database, but virtually all two- and fewer-story units are known to be wood frame).

(e) Includes all facilities in Army code groups 210 through 229, plus 123 and 1212: all maintenance and production facilities for vehicles and stationary equipment of all kinds.

(f) Includes all facilities in Army code group 722 and 74062: unaccompanied personnel dining facilities.

(g) Includes all facilities in Army code groups 131, 133, 171, 610, 620, 730 (none), 14131, 14182, 14183, 14185, 72330, 72360, and 73072: airfield communications, traffic control, training, headquarters, and administrative.

(h) Includes all facilities in Army code groups 124 (none), 143 (none), and 410 through 442: all supply and storage facilities including fuel, dry, and refrigerated.

(i) Includes all facilities in Army code groups 510 through 550 and 73045 - all hospital, clinic, dental, and other medical facilities (not including the New Madigan Hospital). This includes facilities at the Old Madigan area and elsewhere on the post.

(j) These values are based on information from site personnel and manual searches in the building database.

(k) Grand total includes all buildings with number of floors greater than "0," plus major facilities not yet in database and buildings with "0" floors identified as valid conditioned facilities. This value and "other" may be high or low due to database errors, as some buildings have incorrectly identified numbers of floors and missing square footages.

Notes: It appears that many facilities are coded under specific operational categories (e.g., "airfield" or "maintenance") rather than the building types that we are used to. The accuracy of matches of these Army building categories to identified building prototypes will vary. The use of some five-digit categories provided additional detail. Sorting based on the more detailed building descriptions may be more useful. This would, however, require much more effort in scanning the entire database to identify the various building acronyms used for each type and may still be widely inaccurate.

Table A.2 summarizes the building stock by building type served by fossil fuels in terms of heated floorspace, number of buildings, average floorspace by building type, and percent difference from Fort total floorspace.

Specific Notes Concerning Percentage Differences from All Buildings

Some of the concrete and wood barracks and motor pools are known to be no longer used but are still maintained as property. Dining hall facilities

TABLE A.2. Building Stock Served by Fossil Fuel

Building Type	Heated Floorspace (ft^2)	Percentage of Total Heated Floorspace	Number of Buildings	Floorspace (ft^2)	Change From Fort Total Floorspace (%)
Residential	5,882,906	26.7	2,204[(a)]	1,678[(b)]	<1
Concrete Barracks	3,317,976	15.0	78	42,538	-5
Wood Barracks	1,309,439	5.9	276	4,744	-10
Office/ Administration	2,633,975	11.9	636	4,141	-9
Warehouse	1,908,328	8.7	140	13,631	-35
Motor Pool	1,791,642	8.1	199	9,003	-7
Hangar	366,005	1.7	8	45,751	0
Dining Halls	86,880	0.4	17	5,111	-30
Clubs	105,118	0.5	7	15,017	-6
Old Madigan	732,835	3.3	76	9,643	<1
New Madigan	2,000,000	9.1	1	2,000,000	0
Commissary	105,000	0.5	1	105,000	0
Computer Center	15,398	0.1	1	15,398	0
Miscellaneous (no ft^2)[(c)]	NA	NA	5	NA	NA
Other	1,797,826	8.2	269	6,683	-15
Total	22,053,328		3,918		-7.8

(a) Contains total of 3505 living units.
(b) Average floorspace per living unit.
(c) The miscellaneous building type consists of those buildings for which we have fuel bills but not square footage data.

that are attached to barracks in the non-system areas were not identifiable separately from the barracks in terms of fuel use. These were included with barracks, thereby reducing the number of dining halls listed. Some of the newer office structures may be all electric and would therefore not be included in tally.

Nine of the 15 identified building types account for over 90% of the heated square footage. Family housing comprises the largest share of floor-space, accounting for nearly 27% of the total. This is followed by barracks housing for unaccompanied personnel, accounting for nearly 21% of the total. Office/administration buildings comprise the next largest share with almost 12% of the total. These are followed by New Madigan with over 9%, and warehouses, motor pools, and other with over 8% each.

Process Functions and Field Operations

Process functions at Fort Lewis were found to be primarily vehicle wash functions. A majority of this activity was noted by base personnel to be field supported or operated using portable wash units. A portion of the steam supplied to one of the warehouse building areas is used for wash functions. In general, this activity was considered outside the scope of this assessment and the total fuel consumption due to this activity is relatively small. Field operations at Fort Lewis requiring fuel use are noted to be relatively small and erratic. As with process functions, these were outside the scope of this assessment.

Utility Service and Other Energy-Use Characterization

The utility and other energy-use site services present at Fort Lewis include eight primary steam and hot water distribution systems with associated line losses, a sewer and water distribution system, street lighting, and electrical distribution transformer and line losses.

The electrical distribution system comprises approximately 2080 building or group transformers ranging in size from 5 to 2500 kVA. The energy consumption of this distribution system is found in the transformer "load" and "no-load" losses as well as line losses associated with the miles of distribution lines used throughout the Fort.

The eight steam and hot water supply systems at the Fort provide space heating and water heating to areas around the airfield, hospital, and logistics area as follows:

System	Area	Type	Fuel
3LC	Northwest Logistics	Steam	#6 Oil/Gas
5LC	Central Logistics	Steam	#6 Oil/Gas
6	Old Madigan Hospital Area	Steam	#6 Oil/Gas
7	Central Stadium, Theater, Gymnasiums	Steam	#2 Oil/Gas
9	North Section, East of Airfield	Water	#6 Oil/Gas
10	Central Section, East of Airfield	Water	#6 Oil
11	South Section, East of Airfield	Water	#6 Oil
14	Entire Section, West of Airfield	Water	#6 Oil/Gas

The number of buildings and square footage served directly (individual building heating systems - not a part of the eight systems above) and through each of the eight district systems is shown in Table A.3.

Although systems 10 and 11 serve distinct areas, they utilize a common fuel supply system and are not separately metered. For this reason, all further analysis of these two systems is done as one combined system.

Losses associated with these distribution systems are characterized by two primary sectors. The first is leakage of steam or hot water through faulty traps and connections, broken lines, and heat exchanger equipment in need of repair. The second loss comes in the form of thermal losses throughout the system from uninsulated lines.

The Fort water supply is taken from 14 main wells located primarily in the northwestern area of the Fort. Sewage treatment is currently supplied by a central plant in the far northeast corner of the Fort.

Street lighting at the Fort includes military as well as family housing areas. The quantity of street and other exterior lights is estimated at around 10,000 and consists of sodium and mercury vapor technologies.

TABLE A.3. Square Footage and Count of Fossil-Fuel-Use Buildings at Fort Lewis

	Non-System		System 6		System 7		System 9		System 10		System 11		System 14		System 3L		System 5L	
	ft^2	Bldgs	ft^2	Bldg	ft^2	Bldg	ft^2	Bldg	ft^2	Bldg	ft^2	Bldg	ft^2	Bldg	ft^2	Bldg	ft^2	Bldg
Housing:																		
Broadmoor	553,160	120	0		0		0		0		0		0		0		0	
Clarkdale	786,188	160	0		0		0		0		0		0		0		0	
Parkway	353,383	26	0		0		0		0		0		0		0		0	
Greenwood	484,214	151	0		0		0		0		0		0		0		0	
Davis Hill	682,347	433	0		0		0		0		0		0		0		0	
Old Hillside	1,024,176	111	0		0		0		0		0		0		0		0	
Beachwood	761,948	456	0		0		0		0		0		0		0		0	
New Hillside	829,544	524	0		0		0		0		0		0		0		0	
Madigan	200,485	103	0		0		0		0		0		0		0		0	
Evergreen	182,526	115	0		0		0		0		0		0		0		0	
Special 5	24,935	5	0		0		0		0		0		0		0		0	
Barracks (concrete)	960,549	17	0	0	0	0	644,825	17	640,006	19	584,216	14	488,380	11	0	0	0	0
Barracks (wood)	1,305,551	275	3,888	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Motor Pool	989,581	98	7,956	1	0	0	96,561	21	65,204	18	50,517	17	130,195	33	442,020	8	9,608	3
Dining Hall	11,635	5	0	0	0	0	15,375	3	5,125	1	25,625	5	29,120	3	0	0	0	0
Office/ Administration	2,185,612	571	63,761	9	0	0	41,095	9	55,313	16	19,092	6	267,553	24	0	0	1,549	1
Warehouse	1,221,004	96	738	4	0	0	11,449	8	11,881	7	4,756	4	18,904	12	18,029	2	621,567	7
Hanger	213,673	3	0	0	0	0	0	0	0	0	0	0	152,332	5	0	0	0	0
Old Madigan	129,024	10	560,667	60	0	0	3,736	1	16,157	2	3,812	1	19,439	2	0	0	0	0
New Madigan	2,000,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Clubs	90,423	4	9,833	2	0	0	4,862	1	0	0	0	0	0	0	0	0	0	0
Commissary	105,000	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Others	1,307,892	206	103,893	19	75,190	4	54,192	5	140,913	11	21,647	8	74,423	11	7,314	1	12,362	4
Computer/ Simulators	15,398	1	0	0	0	0	0	0	0	0	0	0	54,200	2	0	0	0	0
Totals	16,418,248	3,491	750,736	96	75,190	4	872,095	65	934,599	74	709,665	55	1,234,546	103	467,363	11	645,086	15

A.2 ENERGY SOURCE CHARACTERISTICS

A.2.1 Gas Supply Description

Natural Gas is supplied to Fort Lewis by Washington Natural Gas through underground lines to virtually all areas except the North Fort. Gas is used at all family housing areas, except a portion of Madigan which uses #2 fuel oil. Many of the military operations facilities in the Main Post area also use gas. Natural gas is the primary fuel for 7 of the 8 thermal distribution systems.

A.2.2 Fuel Oil Supply Description

Fuel oil is supplied to the Fort by tanker truck and delivered directly to point-of-use tanks by the contracted oil supplier. It is primarily consumed as #2 and #6 fuel oils. The #2 fuel oil is used in all single building furnaces and boilers on both the Main and North fort areas. It is also used in central thermal distribution system 7. Fuel oil #6 is used exclusively in the remaining seven thermal distribution systems.

A.2.3 Solid Waste Conversion Description

Fort Lewis currently burns a limited amount of solid waste that is used to supplement the heat production on thermal system 9.

A.2.4 Energy Source Summary

The 1989 fuel consumption for non-mobility uses was about 2.5 trillion Btu at a cost of about $12.2 million, distributed as follows by Btu, physical units and value:

	Trillion Btu	Physical Units	Value (million $)
Electricity	0.66	193 GWh	4.5
Natural Gas	1.07	10.7 Million Therms	4.5
#2 Oil	0.43	3.1 Million Gallons	1.9
#6 Oil	0.35	2.3 Million Gallons	1.3
Total	2.53		12.2

A.3 ENERGY-USE INTENSITIES

Energy-use intensities (EUIs) were developed for each of the building types by end-use to support the subsequent development of baseline energy in Section 4.0. The EUIs were developed through a two-step process. The EUIs for the non-system (served directly and not on a district system) buildings were first developed. Then, EUIs for system buildings were developed from the non-system building data and supplemental information.

A.3.1 Non-System Building EUIs

EUIs for buildings not served by one of the eight district systems were developed from actual consumption data. Virtually every building served by natural gas has a gas meter that is read monthly by the serving utility. Fort Lewis is one of a few installations in which this is the case. Delivery tickets provided consumption data for buildings served by #2 fuel oil. The availability of these data eliminated the need to estimate building total EUIs from secondary information and simulation models. Building total EUIs were estimated by totaling the Btu consumption for each building type for both natural gas and #2 fuel oil and dividing by the associated non-system square footage.

The end-use breakdown between space and water heating within the building boundary was estimated using the ratio of space heat to water heat provided in Table A.4. These ratios were largely based on information from regional EUI data sources. These sources drew largely upon metered end-use energy consumption in commercial buildings in the Pacific Northwest. The concrete and wooden barracks space and water heating ratios were based on values calculated from residential housing end-use data.

Sections of housing units in two of the housing areas (Broadmoor and Greenwood) were identified by base personnel as having both water heat and space heat provided by natural gas. Data for a sample of comparable residences with only gas space heat were used to estimate the water heat EUI. Data for summer months' usage, assuming no space heating fossil-fuel use, provided a difference in annualized usage of 32,200 Btu per square foot per

TABLE A.4. EUI Breakout of Space and Domestic Water Heating

Building Types	Ratio of Space Heating to Domestic Water Heating
Office/Administration Computer/Simulators	5.37
Old Madigan New Madigan Commissary	0.50
Dining Hall Club	0.46
Motor Pool Warehouse Hanger	15.86
Other	2.12

year between the homes with and without gas water heat. This was further adjusted by annualized residual usage in the space-heat-only homes of 3,450 Btu per square foot per year. This usage is assumed to be for the furnace pilot light and a small amount of heating. The resulting water heat EUI of 28,750 Btu per square foot per year is consistent with other residential water heating usage estimates provided by natural gas.

Table A.5 shows the fossil-fuel EUIs derived for the non-system buildings for heating, water heat and building total. Fuel use in the New Madigan hospital is estimated to be very small as the facility is not yet in operation.

The average EUI for the residential housing sector is 54,800 Btu per square foot per year. For heating purposes, the average EUI is about 50,000 Btu per square foot per year.

Of the commercial building types, the dining halls, motor pools, and clubs represent the most intense users. The warehouse is the least intensive, having an EUI approximately one-eighth that of the dining halls. Other relatively low energy users for the commercial building types include: hangers, commissary, and the computer center.

TABLE A.5. Fossil-Fuel Building End-Use Intensities (Btu/ft^2/yr)

Building Type	Heating	Water Heating	Total
Residential:			
Broadmoor	28,800	28,800	57,500
Clarkdale	31,200	NA	31,200
Parkway	52,300	NA	52,300
Greenwood	48,900	28,800	77,600
Davis Hill	69,100	NA	69,100
Old Hillside	40,700	NA	40,700
Old Hillside/oil-gas[(a)]	32,700	NA	32,700
Beachwood	45,100	NA	45,100
New Hillside	65,200	NA	65,200
Madigan	55,600	NA	55,600
Madigan/oil[(b)]	71,500	NA	71,500
Evergreen	60,300	NA	60,300
Special 5	48,000	NA	48,000
Commercial:			
Concrete Barracks	39,100	28,800	67,800
With/Dining[(c)]	NA	NA	190,000
Without/Dining[(c)]	NA	NA	100,000
Wood Barracks	37,600	28,800	66,300
Office/Administration	54,800	10,200	65,000
Warehouse	26,100	1,600	27,700
Motor Pool	121,900	7,700	129,600
Hanger	74,400	4,700	79,100
Dining Halls	70,000	152,100	222,100
Clubs	48,100	105,200	153,300
Old Madigan	31,000	61,500	92,500
New Madigan	NA	NA	NA
Commissary	10,600	21,100	31,700
Computer Center	61,900	11,500	73,400
Other	67,800	41,800	109,600

(a) This represents those housing units in Old Hillside that switched from oil to gas during the year 1989. (Others use gas only.)
(b) This represents those housing units in Madigan that use fuel oil only. (Others use gas only.)
(c) These were developed based on PNL metered data as a part of the system building EUI assessment and were used only for buildings on thermal distribution systems. (See Section 3.2.2.)

A.3.2 System Building EUIs

The estimation of fuel use and associated EUI values for buildings served by the eight steam and hot water distribution systems was more involved. Fuel consumption data were available for each of the system plants, but metered data were not available to isolate distribution system losses or building consumption. The first step in developing the building total and end-use EUIs was to subtract estimated distribution system losses. The second step was to estimate the EUIs using total energy input to the eight central plants minus the estimated distribution losses. This estimate included the use of supplemental information such as relative occupancy, spot building metering, and heating plant efficiency estimates.

Distribution System Losses

An important part of the assessment of any steam or hot water thermal distribution system is the amount of loss associated with the distribution lines and equipment. Since each system is different, these losses were estimated for each system.

Fuel use during the early morning hours in August was considered as close to a no-load operation as possible. All of the systems are generally set up to be self-regulating or manually regulated in that the boiler firing rate is matched to meet the load. The boiling firing rates for these time periods were, therefore, considered to be meeting the load (or line losses). The process for assessing this loss was based on an extrapolation of assumed no-load data.

The boiler logs for the first weeks in August of 1990 were obtained from the Fort for five of the eight systems (others were unavailable). Values were extracted from the logs and extrapolated to a full year. This extrapolation took into account the actual number of operating days during the year and utilized the lowest firing rate for each system. Table A.6 shows the estimated yearly loss value for each of the five systems. Also included is the actual value used in the assessment for all eight systems. Finally, the percentage of the total system fuel use that this loss accounts for is shown.

TABLE A.6. Estimated Yearly Distribution Losses at Fort Lewis

System	Extrapolated Loss From Log Data (MBtu)	Loss Value Used In Assessment (MBtu)	% Of Total Estimated System Thermal Use
6	59,300	56,400	45
7	NA	3800	25
9	80,800	48,000	53
10	81,300	NA	NA
11	34,400	NA	NA
10+11	115,700	110,000	46
14	52,000	49,400	26
3LC	NA	16,000	27
5LC	NA	6900	25

Notes: Systems 10 and 11 are served by the same plant. Although each is served by a separate boiler, they share a common gas and oil delivery system. These systems were combined for purposes of the energy-use balance.

No boiler logs were available for systems 7, 3LC, and 5LC.

For systems 6, 10+11, and 14 the losses were considered reasonable and fit well in the balance of the fossil-fuel energy used for that system. Each of these was conservatively reduced by a nominal 5% to arrive at the actual loss value used in the assessment. This was done partially to be conservative and also to account for any stray actual load that may be occurring during the hours used for the extrapolation data.

System 9 losses, as extrapolated from the boiler log data, were the most difficult to reconcile with the other system energy use. Initially, this loss amount, as extrapolated, accounted for close to 90% of the fuel energy use on that system. System 9 supply heat is supplemented all year by an incinerator that accounts for approximately 20% of the total energy delivered to the system. Reducing the loss by this amount to be able (to compare actual fuel-related loss) still left the losses accounting for over 70% of fuel use. Applying this value would have meant allocating an unreasonably low fuel use value to the buildings on the system. No information was available to indicate that occupancy or operation of this system should be that low. To achieve a reasonable balance for this system, a value amounting to about 53% of the total system fuel use was assumed. This allowed for reasonable fuel use for the building stock and was only slightly above the average 45% for the other large systems.

Loss values for systems 7, 3LC, and 5LC were estimated based on losses in other systems. These three systems are much smaller in size than the others and losses (at least based on line length) will be much smaller. A value of approximately half (25%-27%) of the large loop percentage loss was estimated for these systems. In each case the values appeared reasonable and left fuel use assigned to buildings at reasonable levels.

It is important to note that these loss values include several components. These include thermal (conduction) losses in distribution lines, leaks in lines as well as traps and connections, and end-use "losses" such as wash steam that is not used in buildings.

EUI Development

The development of EUI values for those buildings on the steam and hot water systems began by applying the "non-system" building EUIs as initial estimates. Adjustments were made to these values based on specific data available for system buildings and characteristic differences. This included specific electric and steam monitoring of representative buildings and known age, construction, occupancy, and operational differences between system and non-system facilities. As a final adjustment, an energy balance was completed to assure that all system energy was accounted for. This included subtraction of all system losses and any non-building use and allocation of all remaining energy to buildings.

Steam and hot water flow metering as well as electric consumption equipment was installed in representative buildings of the office, motor pool, and concrete/brick barracks types. Two weeks of data were collected during February and March of 1991. Steam and water flow measurements were not obtained for the office buildings because of very low-flow rates due to low or no occupancy. The data collected from the other buildings were extrapolated to provide an estimate of fuel use (fossil and electric) for the year for a typical building and an associated EUI. For this assessment, these estimated system fossil-fuel EUIs were compared with the EUIs developed from the non-system building data to determine an appropriate EUI for those buildings served by the distribution systems. Table A.7 shows the steam/hot water metered data averages, associated estimated system EUI values, and corresponding non-system EUIs.

The average of the values, as derived from the two metered motor pools, came within 12% of the EUI value created from the non-system motor pools. For this assessment, the non-system EUI value was considered representative of a typical motor pool on the base and was also chosen as the initial value for the system motor pool EUI value (prior to adjustment).

Of the four barracks buildings metered, two included integral dining facilities and two did not have dining facilities. The average EUI values calculated from this metered data of 190,000 Btu per square foot per year for "barracks with dining" and 100,000 Btu per square foot per year for "barracks without dining" were considerably higher than the single non-system EUI of 68,000 Btu per square foot per year found for other barracks. Because of the size of this difference, the EUI values derived from the metered data were used for the baseline calculations for each of the two barracks subtypes on the system.

TABLE A.7. Fort Lewis Building Metered Data for EUI Development

Building Type	Bldg #	Bldg Area ft^2	Average MBtu/hr	Heating hr/yr	MBtu/yr	Estimated System EUI $Btu/ft^2/yr$	Non-System EUI $Btu/ft^2/yr$
Motor Pool	3233	4801	98	5040	496	103,000	129,000
Motor Pool	3234	4801	120	5040	603	126,000	129,000
Barracks[a]	3417	40,385	1,430	5376	8350	206,000	68,000
Barracks	3418	40,385	701	5376	4430	109,000	68,000
Barracks[a]	3654	14,000	1,440	5376	8420	166,000	68,000
Barracks	3657	32,400	815	5376	5050	99,000	68,000

(a) These barracks include dining facilities.

After all initial EUI values were set, it was necessary to make adjustments within each systems balance calculation. This is due to various factors including:

- Buildings within each system are not identical to each other or to the non-system buildings because of age and function.
- The occupancy and schedule of non-system and system buildings are not identical.
- The efficiencies of the stand-alone equipment in non-system buildings (used to create the EUIs) are different from those in the system plants.

Within each thermal distribution system, building types were identified that, based on Fort information or other reasoning, might exhibit higher or lower energy intensities than the average defined by the created EUIs. For these buildings or entire systems of buildings, an adjustment factor was introduced to account for these differences. In addition, a system-wide adjustment was made to all system fuel use based on the estimated difference in efficiencies between non-system and system heating equipment. The addition of derived system line losses was also incorporated into the balance (see Section 3.2.1 for details concerning the derivation of line losses). One final adjustment involved an incinerator that supplements the heat production for system 9. Since this supplemental heat was not directly derived from purchased fuel, the value of the incinerator heat was removed in order to achieve an accurate fuel balance. This adjustment is reflected in the building adjustment factor.

The combination of these adjustments was used based on knowledge of the Fort, its operation and equipment, and best engineering judgment to arrive at a balance for each of the eight systems. Table A.8 includes the building use adjustments and plant efficiency factors applied to each thermal distribution system.

A.4 BASELINE ENERGY USE

Tables A.9 and A.10 provide the baseline fossil-fuel energy consumption for system buildings and non-system buildings including distribution losses,

TABLE A.8. Building Use and Plant Efficiency Factors by District Heating System

Building Type	Building Use Factors							
	Sys. 6	Sys. 7	Sys. 9	Sys. 10-11	Sys. 14	Sys. 3LC	Sys. 5LC	Plant Efficiency Factor
Barracks (conc. w/dh)[a]	1	1	0.482	0.75	1.25	1	1	0.875
Barracks (conc. w/o dh)	1	1	0.482	0.75	1.25	1	1	0.875
Barracks (wood)	1	1	0.482	0.75	1.25	1	1	0.875
Motor Pool	1	1	0.482	0.75	1.25	0.85	1	0.875
Dining Hall	1	1	0.482	0.75	1.25	1	1	0.875
Office/Administration	1	1	0.482	0.75	1.25	1	1	0.875
Warehouse	1	1	0.482	0.75	1.25	1	1.2	0.875
Hanger	1	1	0.482	0.75	1.9	1	1	0.875
Old Madigan	1.15	1	0.482	0.75	1.25	1	1	0.875
New Madigan	1	1	0.482	0.75	1.25	1	1	0.875
Clubs	1	1	0.482	0.75	1.25	1	1	0.875
Commissary	1	1	0.482	0.75	1.25	1	1	0.875
Others	1	1.6	0.482	0.75	1.25	1	1	0.875
Computer/Simulators	1	1	0.482	0.75	1.25	1	1	0.875
Loop Line Losses	1	1	0.482	0.75	1.25	1	1	0.875

(a) dh = dining hall.

respectively. These tables detail the use of all primary fossil fuels at Fort Lewis including natural gas, #2 and #6 fuel oil.

Non-system buildings use natural gas or #2 fuel oil, split about 60% and 40%, respectively, between the two fuels. Five of the building types account for 90% of the direct natural gas consumption: residential housing (53%), motor pool (15%), "other" (12%), barracks (6%), and office/administration (4%). Four of the building types account for nearly 90% of the direct #2 fuel oil consumption: office/administration (34%), barracks (23%), "other" (17%), and motor pool (13%). It is estimated that nearly 84% of the energy provided space heat and 16% provided water heat.

TABLE A.9. Estimated Fossil-Fuel Baseline (MBtu) by Building and End Use for Non-Distribution System Facilities

Building Type	Total Gas (MBtu)	HVAC Gas (MBtu)	DHW Gas (MBtu)	Total #2 Oil (MBtu)	HVAC #2 Oil (MBtu)	DHW #2 Oil (MBtu)	Total #6 Oil (MBtu)	HVAC #6 Oil (MBtu)	DHW #6 Oil (MBtu)	Total All Fuels (MBtu)	Percent of Total (%)
Housing:											
Broadmoor	31,816	23,150	8,666	0			0			31,816	3.25
Clarkdale	24,503	24,503		0			0			24,503	2.50
Parkway	18,490	18,490		0			0			18,490	1.89
Greenwood	37,567	32,237	5,330	0			0			37,567	3.84
Davis Hill	47,183	47,183		0			0			47,183	4.82
Old Hillside	40,492	40,492		0			0			40,492	4.14
Old-H/Oil-Gas	285	285		668	668		0			953	0.10
Beachwood	34,347	34,347		0			0			34,347	3.51
New Hillside	54,111	54,111		0			0			54,111	5.53
Madigan	8,964	8,964		0			0			8,964	0.92
Madigan/Oil	0	0		2,798	2,798		0			2,798	0.29
Evergreen	11,002	11,002		0			0			11,002	1.12
Special 5	1,198	1,198		0			0			1,198	0.12
Barracks (concrete)	31,732	19,648	12,084	33,423	20,695	12,727	0			65,154	6.65
Barracks (wood)	2,989	1,825	1,164	83,608	51,049	32,558	0			86,597	8.84
Motor Pool	85,501	81,696	3,805	42,751	40,848	1,902	0			128,252	13.10
Dining Hall	0	0	0	2,584	1,253	1,331	0			2,584	0.26
Office/Administration	22,705	20,034	2,670	119,460	105,411	14,050	0			142,165	14.52
Warehouse	4,082	3,901	181	29,797	28,477	1,321	0			33,880	3.46
Hanger	16,317	15,591	726	576	551	26	0			16,894	1.73
Old Madigan	8,023	4,024	3,999	3,917	1,965	1,953	0			11,940	1.22
New Madigan	0	0	0	0	0	0	0			0	0.00
Clubs	12,200	5,918	6,282	1,660	805	855	0			13,860	1.42
Commissary	3,327	1,114	2,212	0	0	0	0			3,327	0.34
Others	69,902	49,917	19,985	73,412	52,424	20,988	0			143,314	14.64
Computer Center	1,130	952	178	0	0	0	0			1,130	0.12
No. ft^2	16,096	9,964	6,133	505	312	192	0			16,601	1.70
Non-System Total	583,962	510,547	73,414	395,161	307,257	87,903	0	0	0	979,122	100.00
Percent of Total	59.64	52.14	7.50	40.36	31.38	8.98	0.00	0.00	0.00	100.00	

TABLE A.10. Estimated Fossil-Fuel Baseline (MBtu) by Building and End Use for All Distribution System Facilities

Building Type	Total Gas (MBtu)	HVAC Gas (MBtu)	DHW Gas (MBtu)	Total #2 Oil (MBtu)	HVAC #2 Oil (MBtu)	DHW #2 Oil (MBtu)	Total #6 Oil (MBtu)	HVAC #6 Oil (MBtu)	DHW #6 Oil (MBtu)	Total All Fuels (MBtu)	Percent of Total (%)
Barracks (conc. w/dh)	22,176	12,793	9,383	0	0	0	43,150	24,892	18,257	65,326	8.71
Barracks (conc. w/o dh)	44,932	25,920	19,011	0	0	0	82,942	47,848	35,094	127,873	17.06
Barracks (wood)	218	133	85	0	0	0	7	5	3	226	0.03
Motor Pool	42,933	40,640	2,293	0	0	0	35,242	33,360	1,882	78,175	10.43
Dining Hall	3,035	2,928	107	0	0	0	9,961	9,611	350	12,996	1.73
Office/Administration	5,867	5,039	828	0	0	0	21,188	18,198	2,990	27,055	3.61
Warehouse	18,694	17,700	994	0	0	0	881	834	47	19,576	2.61
Hanger	68	65	4	0	0	0	19,955	18,889	1,065	20,023	2.67
Old Madigan	51,161	20,562	30,599	0	0	0	4,376	1,759	2,617	55,537	7.41
New Madigan	0	0	0	0	0	0	0	0	0	0	0.00
Clubs	1,482	566	916	0	0	0	151	58	93	1,633	0.22
Commissary	0	0	0	0	0	0	0	0	0	0	0.00
Others	29,129	19,136	9,993	827	543	284	16,540	10,866	5,675	46,496	6.20
Computer Center	15	13	2	0	0	0	4,334	3,721	613	4,349	0.58
Distribution Losses	159,668	105,734	53,934	272	179	93	130,443	92,912	37,531	290,383	38.74
All System Total	379,378	251.229	128,149	1,099	722	377	369,171	262,953	106,218	749,648	100.00
Percent of Total	50.61	33.51	17.09	0.15	0.10	0.05	49.25	35.08	14.17	100.00	

Of total fuel consumed by buildings served by the district systems, 51% was natural gas, less than 1% by #2 fuel oil and 49% by #6 fuel oil. Distribution losses were estimated to be approximately 39% of the total energy supplied to the eight central boilers. Of the energy supplied to the buildings (energy input to the boilers less distribution losses) in the form of natural gas, 95% was accounted for by five building types: concrete barracks (31%); motor pool (20%); warehouse (8%); Old Madigan (23%); and other (13%). It is estimated that all of the #2 fuel oil was consumed by the "other" category. Approximately 92% of #6 fuel oil was consumed in five building types: concrete barracks (53%); motor pool (15%); office/administration (9%); hangar 8%; and other (7%). It is estimated that 69% of the energy provided space heat and 31% provided water heat.

Of the total fossil-fuel energy provided to ALL buildings and other uses, 57% is consumed within building boundaries, 27% is provided to buildings through the district systems, and 17% is in the form of distribution losses. Natural gas accounts for 56% of total fossil energy consumption, 60% of which is consumed within building boundaries and 40% to the district systems. Virtually 100% of fuel oil #2, which accounts for 23% of total fossil energy consumption, is consumed within building boundaries. Fuel oil #6 provides 21% of total fossil energy use and is allocated 100% to the district systems. Several of the building types were larger consumers of fossil fuels, both directly and from the distribution system. These types are: barracks (20% of total fossil-fuel use), residential (18%), motor pool (12%), "other" (11%), and office/administration (10%). The noted five building types account for about 70% of the Fort's fossil energy consumption.

The combination of the fuel use totals of the non-system and system facilities completes a fossil-fuel balance for the entire Fort. Table A.11 shows the total fuel use by fuel type for the Fort as derived by this process. Also shown are Fort Billing Total values based on Fort information.

The estimated energy use of 1,728,770 million Btu for all fossil fuels was not adjusted to match the actual of 1,752,426 million Btu from billing data. For the Fort, this baseline accounts for 94% of the natural gas use, 98% of the #2 fuel oil use, and 112% of the #6 fuel oil use.

TABLE A.11. Fort Lewis Estimated Total Fossil-Fuel Use (MBtu) Comparison with Billing Values

	Natural Gas	#2 Fuel Oil	#6 Fuel Oil	Total
Non-System Total	583,962	395,161	0	979,122
All System Total	379,378	1,099	369,171	749,648
All Base Estimated Total	963,340	396,260	369,171	1,728,770
Fort Billing Total	1,019,039	403,842	329,545	1,752,426
Percent Difference	94.5	98.1	112	99

A.5 THERMAL DISTRIBUTION SYSTEM BREAKDOWN

An analysis of each thermal distribution system was completed as a part of the Fort Lewis EUI and energy consumption baseline. Fuel use, building types, square footages, operation, occupancy, plant characteristics and line loss data were collected or derived for analysis of each system. Each system's total fuel consumption was used to calibrate the final allocation of all energy to buildings and other uses.

The allocation of fuel use between the primary end-uses (space heating and domestic water heating) was based on EUI data collected for the Fort Lewis area and climate conditions. Data supplied by PNL on-site metering was also used. All but one of the eight (analyzed as seven) primary systems used both natural gas and fuel oil during the course of the base year. In order to allocate each different fuel to its appropriate use, a ratio of fuel use in each system was derived. This ratio was then applied to all fuel use in all end-uses. Appropriate weighting of each fuel use was accomplished in this manner. The ratios, shown in Table A.12 as a percentage of total fuel, are based directly on total reported fuel use for the 1989 base year for each system plant.

This data was used along with the building and plant efficiency adjustment factors and the line loss data to allocate the energy use of each system among all uses. Tables A.13 through A.19 provide details on the allocation of fuel use to buildings, end-uses, and losses for each of the thermal systems.

TABLE A.12. Fossil-Fuel Use Percentages of Total for Systems at Fort Lewis

System	Percentage of Total Fossil Fuel		
	Natural Gas	#2 Oil	#6 Oil
6	96.7	0.0	3.3
7	92.8	7.2	0.0
9	65.8	0.0	34.2
10/11	46.0	0.0	54.0
14	0.3	0.0	99.7
3LC	77.2	0.0	22.8
5LC	100	0.0	0.0

TABLE A.13. System 6 Baseline Energy Use by Building Type, Fuel Type, and End Use

System 6 Building Type	Gas (therms)	Total Gas (MBtu)	HVAC Gas (MBtu)	DHW Gas (MBtu)	#2 Oil (gallons)	Total #2 Oil (MBtu)	HVAC #2 Oil (MBtu)	DHW #2 Oil (MBtu)	#6 Oil (gallons)	Total #6 Oil (MBtu)	HVAC #6 Oil (MBtu)	DHW #6 Oil (MBtu)	Total All Fuels (MBtu)
Barracks (conc. w/dh)	0	0	0	0	0	0	0	0	0	0	0	0	0
Barracks (conc.)	0	0	0	0	0	0	0	0	0	0	0	0	0
Barracks (wood)	2,183	218	133.2649	84.99406	0	0	0	0	49	7	4.515013	2.879597	226
Motor Pool	8,727	873	826.0582	46.60168	0	0	0	0	196	30	27.98684	1.578864	902
Dining Hall	0	0	0	0	0	0	0	0	0	0	0	0	0
Office/Administration	35,100	3,510	3014.663	495.3769	0	0	0	0	787	119	102.1367	16.78336	3,629
Warehouse	173	17	16.40891	0.921893	0	0	0	0	4	1	0.555933	0.031234	18
Hanger	0	0	0	0	0	0	0	0	0	0	0	0	0
Old Madigan	505,001	50,500	20296.55	30203.58	0	0	0	0	11,323	1,711	687.6466	1023.297	52,211
New Madigan	0	0	0	0	0	0	0	0	0	0	0	0	0
Clubs	12,756	1,276	487.3904	788.2198	0	0	0	0	286	43	16.51278	26.70487	1,319
Commissary	0	0	0	0	0	0	0	0	0	0	0	0	0
Others	96,348	9,635	6329.299	3305.455	0	0	0	0	2,160	326	214.4365	111.9887	9,961
Computer/Simulators	0	0	0	0	0	0	0	0	0	0	0	0	0
Loop Line Losses	545,367	54,537			0	0			12,228	1,848			56,384
Total	1,205,655	120,565			0	0			27,033	4,085			124,650

TABLE A.14. System 7 Baseline Energy Use by Building Type, Fuel Type, and End Use

System 7 Building Type	Gas (therms)	Total Gas (MBtu)	HVAC Gas (MBtu)	DHW Gas (MBtu)	#2 Oil (gallons)	Total #2 Oil (MBtu)	HVAC #2 Oil (MBtu)	DHW #2 Oil (MBtu)	#6 Oil (gallons)	Total #6 Oil (MBtu)	HVAC #6 Oil (MBtu)	DWH #6 Oil (MBtu)	Total All Fuels (MBtu)
Barracks (conc. w/o dh)	0	0	0	0	0	0	0	0	0	0			0
Barracks (wood)	0	0	0	0	0	0	0	0	0	0			0
Motor Pool	0	0	0	0	0	0	0	0	0	0			0
Dining Hall	0	0	0	0	0	0	0	0	0	0			0
Office/Administration	0	0	0	0	0	0	0	0	0	0			0
Warehouse	0	0	0	0	0	0	0	0	0	0			0
Hanger	0	0	0	0	0	0	0	0	0	0			0
Old Madigan	0	0	0	0	0	0	0	0	0	0			0
New Madigan	0	0	0	0	0	0	0	0	0	0			0
Clubs	0	0	0	0	0	0	0	0	0	0			0
Commissary	0	0	0	0	0	0	0	0	0	0			0
Others	107,081	10,708	7034.373	3673.677	5,955	827	543.015	283.587	0	0			11,535
								7					
Computer/Simulators	0	0	0	0	0	0	0	0	0	0			0
Loop Line Losses	35,277	3,528			1,962	272			0	0			3,800
Total	142,357	14,236			7,917	1,099			0	0			15,335

TABLE A.15. System 9 Baseline Energy Use by Building Type, Fuel Type, and End Use

System 9 Building Type	Gas (therms)	Total Gas (MBtu)	HVAC Gas (MBtu)	DHW Gas (MBtu)	#2 Oil (gallons)	Total #2 Oil (MBtu)	HVAC #2 Oil (MBtu)	DHW #2 Oil (MBtu)	#6 Oil (gallons)	Total #6 Oil (MBtu)	HVAC #6 Oil (MBtu)	DWH #6 Oil (MBtu)	Total All Fuels (MBtu)
Barracks (conc. w/dh)	69,690	6,969	4020.332	2948.716	0	0			23,972	3,622	2089.557	1532.588	10,591
Barracks (conc. w/o dh)	142,268	14,227	8207.227	6019.599	0	0			48,937	7,394	4265.686	3128.671	21,621
Barracks (wood)	0	0	0	0	0	0			0	0	0	0	0
Motor Pool	34,729	3,473	3287.482	185.4617	0	0			11,946	1,805	1708.66	96.39326	5,278
Dining Hall	9,477	948	363.5108	584.1543	0	0			3,260	493	188.9338	303.6127	1,440
Office/Administration	7,418	742	637.1158	104.6924	0	0			2,552	386	331.1393	54.41363	1,127
Warehouse	882	88	83.47119	4.689619	0	0			303	46	43.38394	2.437418	134
Hanger	0	0	0	0	0	0			0	0	0	0	0
Old Madigan	959	96	38.5631	57.38629	0	0			330	50	20.04307	29.82638	146
New Madigan	0	0	0	0	0	0			0	0	0	0	0
Clubs	2,068	207	79.02266	127.7974	0	0			711	107	41.07183	66.42237	314
Commissary	0	0	0	0	0	0			0	0	0	0	0
Others	16,479	1,648	1082.556	565.361	0	0			5,668	857	562.6556	293.8449	2,504
Computer/Simulators	0	0	0	0	0	0			0	0	0	0	0
Loop Line Losses	315,842	31,584			0	0			108,642	16,416			48,000
Total	599,813	59,981			0	0			206,321	31,175			91,156

TABLE A.16. Systems 10 and 11 Baseline Energy Use by Building Type, Fuel Type, and End Use

Systems 10 and 11 Building Type	Gas (therms)	Total Gas (MBtu)	HVAC Gas (MBtu)	DHW Gas (MBtu)	#2 Oil (gallons)	Total #2 Oil (MBtu)	HVAC #2 Oil (MBtu)	DHW #2 Oil (MBtu)	#6 Oil (gallons)	Total #6 Oil (MBtu)	HVAC #6 Oil (MBtu)	DWH #6 Oil (MBtu)	Total All Fuels (MBtu)
Barracks (conc. w/dh)	151,324	15,132	8,730	6,403	0	0	0	0	117,413	17,741	10,235	7,507	32,873
Barracks (conc. w/o dh)	305,690	30,569	17,635	12,934	0	0	0	0	237,185	35,839	20,675	15,164	66,408
Barracks (wood)	0	0	0	0	0	0	0	0	0	0	0	0	0
Motor Pool	45,306	4,531	4,289	242	0	0	0	0	35,153	5,312	5,028	284	9,842
Dining Hall	20,632	2,063	791	1,272	0	0	0	0	16,008	2,419	928	1,491	4,482
Office/Administration	14,620	1,462	1,256	206	0	0	0	0	11,344	1,714	1,472	242	3,176
Warehouse	1,395	139	132	7	0	0	0	0	1,082	163	155	9	303
Hanger	0	0	0	0	0	0	0	0	0	0	0	0	0
Old Madigan	5,583	558	224	334	0	0	0	0	4,332	655	263	391	1,213
New Madigan	0	0	0	0	0	0	0	0	0	0	0	0	0
Clubs	0	0	0	0	0	0	0	0	0	0	0	0	0
Commissary	0	0	0	0	0	0	0	0	0	0	0	0	0
Others	53,810	5,381	3,535	1,846	0	0	0	0	41,751	6,309	4,144	2,164	11,690
Computer/Simulators	0	0	0	0	0	0	0	0	0	0	0	0	0
Loop Line Losses	505,942	50,594			0	0			392,561	59,316			109,910
Total	1,104,301	110,430			0	0			856,829	129,467			239,897

TABLE A.17. System 14 Baseline Energy Use by Building Type, Fuel Type, and End Use

System i4 Building Type	Gas (therms)	Total Gas (MBtu)	HVAC Gas (MBtu)	DHW Gas (MBtu)	#2 Oil (gallons)	Total #2 Oil (MBtu)	HVAC #2 Oil (MBtu)	DHW #2 Oil (MBtu)	#6 Oil (gallons)	Total #6 Oil (MBtu)	HVAC #6 Oil (MBtu)	DWH #6 Oil (MBtu)	Total All Fuels (MBtu)
Barracks (conc. w/dh)	746	75	43.04908	31.57439	0	0			144,187	21,787	12568.33	9218.257	21,861
Barracks (conc. w/o dh)	1,360	136	78.46212	57.54811	0	0			262,797	39,709	22907.3	16801.38	39,845
Barracks (wood)	0	0	0	0	0	0			0	0	0	0	0
Motor Pool	630	63	59.63366	3.364205	0	0			121,724	18,392	17410.26	982.1916	18,455
Dining Hall	241	24	9.262519	14.88468	0	0			46,657	7,050	2704.226	4345.635	7,074
Office/Administration	650	65	55.80522	9.170051	0	0			125,544	18,970	16292.53	2677.229	19,035
Warehouse	20	2	1.854207	0.104174	0	0			3,784	572	541.3425	30.41397	574
Hanger	683	68	64.6993	3.648962	0	0			132,062	19,955	18889.19	1065.328	20,023
Old Madigan	67	7	2.699446	4.017083	0	0			12,978	1,961	788.1128	1172.802	1,968
New Madigan	0	0	0	0	0	0			0	0	0	0	0
Clubs	0	0	0	0	0	0			0	0	0	0	0
Commissary	0	0	0	0	0	0			0	0	0	0	0
Others	304	30	20.00128	10.4456	0	0			58,829	8,889	5839.446	3049.63	8,920
Computer/Simulators	148	15	12.7451	2.09986	0	0			28,683	4,334	3720.976	613.0617	4,349
Loop Line Losses	1,686	169			0	0			325,745	49,220			49,389
Total	6,537	654			0	0			1,262,989	190,838			191,491

TABLE A.18. System 3LC Baseline Energy Use by Building Type, Fuel Type, and End Use

System 3LC Building Type	Gas (therms)	Total Gas (MBtu)	HVAC Gas (MBtu)	DHW Gas (MBtu)	#2 Oil (gallons)	Total #2 Oil (MBtu)	HVAC #2 Oil (MBtu)	DHW #2 Oil (MBtu)	#6 Oil (gallons)	Total #6 Oil (MBtu)	HVAC #6 Oil (MBtu)	DWH #6 Oil (MBtu)	Total All Fuels (MBtu)
Barracks (conc. w/dh)	0	0			0	0			0	0			0
Barracks (conc. w/o dh)	0	0			0	0			0	0			0
Barracks (wood)	0	0			0	0			0	0			0
Motor Pool	329,038	32,904	31146.67	1757.125	0	0			64,217	9,703	9185.057	518.1706	42,607
Dining Hall	0	0	0	0	0	0			0	0	0	0	0
Office/Administration	0	0	0	0	0	0			0	0	0	0	0
Warehouse	3,380	338	320.0589	17.9817	0	0			660	100	94.38437	5.302749	438
Hanger	0	0	0	0	0	0			0	0	0	0	0
Old Madigan	0	0	0	0	0	0			0	0	0	0	0
New Madigan	0	0	0	0	0	0			0	0	0	0	0
Clubs	0	0			0	0			0	0			0
Commissary	0	0			0	0			0	0			0
Others	5,416	542	355.7617	185.7953	0	0			1,057	160	104.913	54.79047	701
Computer/Simulators	0	0			0	0			0	0			0
Loop Line Losses	123,562	12,356			0	0			24,115	3,644			16,000
Total	461,396	46,140			0	0			90,049	13,606			59,746

TABLE A.19. System 5LC Baseline Energy Use by Building Type, Fuel Type, and End Use

System 5LC Building Type	Gas (therms)	Total Gas (MBtu)	HVAC Gas (MBtu)	DHW Gas (MBtu)	#2 Oil (gallons)	Total #2 Oil (MBtu)	HVAC #2 Oil (MBtu)	DHW #2 Oil (MBtu)	#6 Oil (gallons)	Total #6 Oil (MBtu)	HVAC #6 Oil (MBtu)	DWH #6 Oil (MBtu)	Total All Fuels (MBtu)
Barracks (conc. w/dh)	0	0			0	0			0	0			0
Barracks (conc. w/o dh)	0	0			0	0			0	0			0
Barracks (wood)	0	0			0	0			0	0			0
Motor Pool	10,896	1,090	1031.381	58.18485	0	0			0	0			1,090
Dining Hall	0	0	0	0	0	0			0	0			0
Office/Administration	882	88	75.71906	12.44234	0	0			0	0			88
Warehouse	181,093	18,109	17145.99	963.3045	0	0			0	0			18,109
Hanger	0	0	0	0	0	0			0	0			0
Old Madigan	0	0	0	0	0	0			0	0			0
New Madigan	0	0	0	0	0	0			0	0			0
Clubs	0	0			0	0			0	0			0
Commissary	0	0			0	0			0	0			0
Others	11,853	1,185	778.6247	406.6341	0	0			0	0			1,185
Computer/Simulators	0	0			0	0			0	0			0
Loop Line Losses	69,000	6,900			0	0			0	0			6,900
Total	273,723	27,372			0	0			0	0			27,372

APPENDIX B

<u>RESOURCE ASSESSMENT</u>

APPENDIX B

RESOURCE ASSESSMENT

B.1 ENERGY-EFFICIENCY MEASURE SCREENING

This appendix provides the listing of 61 efficiency measures that were investigated for potential implementation at Fort Lewis. Consultation with Fort Lewis staff, energy-conservation experts, and PNL staff screened the list to 35 that were analyzed for efficiency potential and cost-effectiveness. A description of the measures considered and not considered is contained in this section.

B.1.1 Efficiency Measures Considered

Building Envelope Measures

The current insulation level of the building envelope and the building age were major factors affecting implementation of ECOs in this group. This was often difficult to discern because of the large number of building types and their widely varying ages. Discussions with Fort Lewis staff were helpful to ascertain the general condition of the buildings and to gain a history of retrofit measures the Fort has taken in the past. These ECOs affect space-heating fuel use only:

- Insulate suspended ceilings of commercial buildings >20 years with batt-type, non-rigid insulation from R-11 to R-19.
- Insulate attic ceilings of wood frame buildings (residential and wooden barracks) with batt-type, non-rigid insulation from R-11 to R-19.
- Blow-in wall insulation for wooden frame buildings from a base R-11 insulation value (supplied by solid foam insulation) to R-19.
- Insulate interior brick surface walls with furring strips and fire-proof gypsum board to hold the insulation in place. This was considered for only a portion of the concrete barracks.
- Insulate perimeter of slab-on-grade below surface to an R-7.7 level for residential housing.

- Insulate floor above crawl space by hanging insulation from the current R-3 level to R-11 on 75% of the wooden barracks. Material costs include the batt-type insulation, wire mesh, and vapor barrier costs but not the costs associated with skirting about the perimeter of the building, because air flow is necessary to prevent condensation buildup.

- Install storm windows as a retrofit on 30% of the windows in concrete barracks.

- Caulk and weatherstrip windows and leaks to reduce infiltration on buildings that serve as residences (residential housing and wooden and concrete barracks).

<u>Building Auxiliary Heating Measures</u>

These ECOs affect space-heating fuel use only:

- Install infrared heaters for radiation heating of limited spaces within large areas including hangars, motor pools, and warehouse building types.

- Install programmable setback thermostat controls. Mechanical, pin-operated setback thermostats have been tried at Fort Lewis with limited success. Uncomplicated, user-friendly programmable thermostats are available that may provide a more effective conservation measure.

<u>Water Heating Measures</u>

These ECOs affect domestic hot water fuel use only:

- Install low-flow shower heads in the remaining available locations. From discussions with Fort Lewis staff, it was determined that this ECO is being implemented when replacement is necessary. A penetration rate of 30% was used in this assessment to account for the shower heads that have not been replaced with this conservation measure.

- Insulate DHW pipes in buildings that serve as residences (residential housing and wooden and concrete barracks). Because most DHW pipes are confined in the building's walls, this assessment considered only that a small exposed portion (10 feet) of the total DHW pipe length would be economical to retrofit.

- Install specially lined (non-corrosive) gas water heaters. This ECO is part of a fuel-switching option outlined below.

Boiler Measures

Boiler capacity (MBtu/hr) and age, and fuel type were the main factors affecting implementation of ECOs in this group. Typically, the Fort Lewis main plant boilers for central steam distribution ranged from 5 to 60 MBtu/hr. The boilers dedicated to a building unit typically ranged in size from 0.2 to 1 MBtu/hr. These ECOs affected space-heating fuel use only:

- Install a combustion air preheater to reduce energy losses in the boiler flue. Applicable to capacities >40 MBtu/hr.
- Install feedwater economizers in the boiler flue to preheat condensate return and make-up water. Applicable to capacities >3 MBtu/hr.
- Install air-atomizing burners and low excess air (LEA) burners for oil-burning boilers to increase combustion efficiency. Applicable to all sizes of oil burners; increased efficiency is related to the age of the retrofit boiler.
- Perform boiler tuneup by optimizing air-to-fuel ratios. Applicable to all boiler sizes and should be performed once a year.
- Install flue gas analyzers to assist in maintaining optimal boiler efficiency. Applicable to capacities >10 MBtu/hr.
- Install automatic electric dampers to reduce standby loss when the boiler is not in use. Applicable to all boiler sizes; most effective with boilers that cycle diurnally.
- Install new and more efficient oil- or gas-burning conventional boilers. Applicable to capacities <25 MBtu/hr; it is thought that the high capital costs associated with capacities greater than this would warrant a more detailed study by each individual boiler case. This ECO is part of a fuel-switching option outlined below.
- Install new gas pulse or condensing boilers to replace older, less efficient oil boilers. Applicable to capacities <1 MBtu/hr. This ECO is part of a fuel-switching option outlined below.
- Install fire-tube turbulators in fire-tube boilers to improve overall combustion efficiency. Applicable to boilers between 1 and 20 MBtu/hr that are older than 15 years.
- Replace manual boiler blow-down system with a continuous boiler blow-down system with heat-recovery capability. Applicable to capacities >6 MBtu/hr.

- Install oxygen trim control to maintain low excess air levels. Applicable to all boiler sizes.

- Provide maintenance of existing feedwater economizers found on larger (>3 MBtu/hr) boilers.

District Thermal Distribution Measures

The steam- and fuel-line diameters and current insulation levels, as well as the capacity and age of the main plant boilers and thermal distribution lines, were important factors affecting the level of implementation of the ECOs in this category. Discussions with Fort Lewis staff and energy conservation experts were helpful in developing the potential strategy for implementing these ECOs. One of the consulting experts has gained considerable experience in this area while working at UCLA. These ECOs affect space-heating fuel use only:

- Repair or replace defective steam traps. The number of defective traps is largely dependent on the size of the distribution system, including the number of buildings, mechanical control rooms, heating coils within the buildings, and the length of pipe both above and below ground.

- Insulate buried pipe of main distribution lines. This assessment considers insulating only a small portion (15%) of the buried distribution lines because of accessibility and locating problems.

- Insulate above-ground pipe of main distribution lines. This would largely affect distribution line above ground not found in the building's interior where thermal losses could be a source of space heating.

- Insulate hot fuel-oil pipes leading from the heater to the burner within the boiler. Of the ECOs considered at Fort Lewis, asbestos abatement programs will largely affect only the piping insulation measures. Much of the piping insulation that is 20 to 30 years old contains asbestos. Asbestos removal and/or abatement can include the following costs: asbestos removal equipment, preparing area for asbestos removal, demolition, disposal of asbestos-laden material, cleanup after demolition, encapsulation, and OSHA testing. These activities can be expensive. Past abatement programs at Fort Lewis have mainly focused on encapsulating the asbestos insulation with an epoxy-like sealant and applying new insulation rather than removing the asbestos.

- Locate steam mass losses in buried steam distribution lines with infrared (IR) technology and repair the leaks. This is a proven technology that uses a special camera and video screen to detect leaks. It can detect temperature differentials as low as 0.1°C and locate leaks up to 6 feet below the ground level, depending on the size of the leak. The IR scanning is most effective at night when the effect of sunlight can be isolated, during cold weather (at which time the thermal distribution system may be operating at near maximum capacity, and the thermal differential may be most intense), and when the scanning takes place from an elevated vantage point, such as a rooftop. In addition, the soil at Fort Lewis is largely a mixture of gravel and rock moraine material left from Ice Age glaciation. This soil type has excellent drainage characteristics, allowing for additional contrast in areas of steam leaks. Losses in condensate return lines are typically low because of low line pressure and temperature.

- Install water-to-water heat exchangers for heat recovery in dining hall facilities.

- Insulate hot water storage tanks.

Fuel-Switching Opportunities

Fuel-switching is another area of conservation potential. While efficiency improvements are possible with new technologies (e.g., the specially lined, non-corrosive water heaters are more efficient than the conventional electric water heaters), fuel-switching can allow the consumer to take advantage of more economical fuel choices. Fuel-switching opportunities investigated for Fort Lewis include the following:

- Switch old oil boiler to a conventional gas boiler.

- Switch old oil boiler to a gas pulse combustion boiler.

- Switch conventional electric water heater to a specially lined gas water heater with the following two scenarios:

    1. Replace 100% of existing conventional water heaters with the specially lined gas water heaters all at once.

    2. Information from Fort Lewis staff indicates that the life expectancy of the existing water heaters is less than five years due to tank corrosion caused by carbonic acid. Replace 20% of the existing conventional water heaters with the specially lined gas water heaters each year.

B.1.2 Efficiency Measures Not Considered

A number of additional resource opportunities identified by this assessment were not further investigated for implementation at Fort Lewis because 1) it is believed they did not offer an adequate level of efficiency resource potential; 2) they could only be addressed through a more focused data collection effort, which is beyond the scope of this initial effort; and/or 3) they did not involve a retrofit or installation and were focused primarily on maintenance or operation scheduling. Because of the temperate climate in which Fort Lewis exists, no cooling system conservation measures were considered for the Fort. The resource opportunities by end-use sector that were not considered follow.

Building Envelope Measures

- Insulate roof. This measure involves demolishing the existing roof, providing required insulation, and installing a new roof. This costly measure may be more effectively replaced by insulating a portion of the ceiling plenum or attic space.
- Insulate crawl space by filling entire cavity. This would eliminate ventilation and air movement within the crawl space, allowing condensate to accumulate which could lead to deterioration of the floor structure.
- Insulate supply and return ducts. Only limited information was available for characterizing this measure at Fort Lewis and was, therefore, not considered.
- Install vapor barriers in walls, ceilings, and roofs.
- Install reflective roof surfaces and tinted or reflective windows. This is a cooling-system ECO.
- Adjust space temperature and humidity settings.
- Reduce window area in building.

Building Auxiliary Heating

- Replace current residential space heating equipment with small boilers (hydronics).
- Install hot water supply temperature reset control system.
- Install supply air temperature reset control system.

Water Heating Measures

- Lower hot water temperatures. Domestic hot water temperatures are normally maintained at a minimum of 140°F to prevent harmful bacteria growth.

- Reduce operating hours for water heating systems.

- Reduce hot water loads.

- Preheat boiler feedwater with reclaimed waste heat from a dining hall or laundry use.

Boiler Measures

- Install barometric dampers. These dampers are less reliable than the slightly more expensive automatic electric dampers.

- Replace district thermal distribution systems with individual boilers. This measure would reduce much of the thermal and mass losses associated with the district systems; however, the larger-capacity district system boilers are usually better maintained and operate with efficiencies higher than that of stand-alone boilers. Maintenance and service costs would likely be greater with many individual boilers.

- Clean boiler surfaces of fouling.

- Improve feedwater chemical treatment to reduce fouling. Operation costs would likely be greater due to the potential increase in manpower needs for adjustment of steam traps and other distribution components.

- Reduce boiler steam pressure/temperature.

- Optimize boiler operating schedule.

- Insulate the boiler.

District Thermal Distribution Measures

- Heating fuel oil. This is an important measure that is, however, usually already in place for highly viscous oils (such as residual #6 oil). Typically, a tank outlet heater is used to heat the oil as it leaves the tank to 140°F,and a second heater located just prior to the burner section of the boiler heats the oil to approximately 190°F.

- Insulate fuel-oil tanks. Because it is only necessary to heat the fuel oil at the outlet of tne tank, it is generally not essential to insulate the entire storage tank.

- Insulate manhole covers.

- Reduce steam and condensate flow rates in pipes.

Fuel-Switching Opportunities

- Dual-fuel burners on boilers. These are generally effective for boiler capacities >1 MBtu/hr. Because the main plant boilers at Fort Lewis are already on interruptible rates, they either currently have dual-fuel capabilities or they have alternate means to provide for the necessary space heating requirements. This leaves a very small number of large boilers that could benefit from dual-fuel capabilities.

B.2 ENERGY-EFFICIENCY MEASURE EVALUATION

This section describes the six categories of energy-efficiency measures considered at Fort Lewis. These are building envelope, building auxiliary heating, water heating, boiler measures, district system measures, and fuel-switching opportunities. The discussion of each measure category contains a brief description of the analytical procedure, assumptions employed, and analysis results, which include the annual energy savings, value of energy savings, levelized operation and maintenance costs (O&M), the net present value (NPV) of the various measures broken down by sector, end use, and fuel type. The sectors are identified as residential buildings (Res), non-residential non-district system buildings (Non Res/Non Sys), non-residential district system buildings (Non Res/Sys) and district thermal distribution system (Dist Sys). Within each of these sectors, the analysis of the measures was conducted by type of fuel consumed, fuel oil #2 (FO2), fuel oil #6 (FO6), natural gas (NG) and electricity.

B.2.1 Analysis of Building Envelope Measures

This section discusses the analysis of the eight building envelope measures considered. These are primarily insulation retrofit measures that affect suspended ceilings, attics, walls, perimeter of slab-on-grade, and crawl spaces, as well as installing storm windows and caulking and weatherstripping windows to reduce infiltration.

Analytical Procedure

Energy savings calculations developed for building envelope measures were derived from procedures in ASHRAE Fundamentals. For each measure, both the current and post-measure installation heat loss was calculated. The difference between the two heat loss values is the energy savings.

Several inputs are required to calculate heat loss for measures that increase the thermal resistance of building envelope components (e.g., ceiling, attic, wall, floor, storm windows, slab-on-grade, etc.). These include heat transfer coefficient [Btu/(hrft^2)], area of affected surface (ft^2), site-specific heating degree days [(°Fday)/yr], and a correction factor correlated to the heating degree day value. In addition, the efficiency of the heating source (boiler, furnace, etc.) is accounted for in the calculation algorithm. The total heat loss is divided by the efficiency factor to account for the additional energy required to supply the heat which actually enters the building envelope.

Associated with each measure is a penetration rate. This rate is occasionally less than one and occurs when it is not possible to install the measure in all the potential area (e.g., reaching all the potential crawl space area with insulation may not be possible without extensive excavation).

The measures that save energy by reducing heat loss through infiltration are caulking and weatherstripping. Requisite inputs for energy savings calculations include: specific heat (Btu/(lbm°F)) and density (lbm/ft^3) of air, building volume (ft^3), percent reduction in infiltration, and site-specific heating degree days [(°Fday)/yr].

Results

The results of the analysis of the building envelope measures are located in Table B.1. There were eight measure types applied resulting in 32 cases in which the measure energy savings, cost, net present value and value index were calculated. Of the 32 cases, 11 had positive net present values.

TABLE B.1. Building Envelope Efficiency Measures--Cost, Quantity and Value of Energy Efficiency Improvements

Energy Conservation Measure Category	Sector	Energy Conservation Measure	Existing Fuel	Resulting Fuel	Initial Capital Cost (1991 $)	Present Value of O&M Costs (1991 $)	Annual Energy Savings (MBtu)	Value of Annual Energy Savings (1991 $)	NPV of Strategy (1991 $)	Value Index
Bldg. Envelope	Non Res/Non Sys	Insulate suspended ceilings	F02	F02	56,628	0	1,010	7,494	75,131	1.33
Bldg. Envelope	Non Res/Non Sys	Insulate suspended ceilings	NG	NG	20,831	0	372	1,190	-1,931	-0.09
Bldg. Envelope	Non Res/Sys	Insulate suspended ceilings	F06	F06	46,360	0	821	5,375	81,917	1.77
Bldg. Envelope	Non Res/Sys	Insulate suspended ceilings	NG	NG	48,052	0	851	1,788	-14,726	-0.31
Bldg. Envelope	Non Res/Non Sys	Insulate attic ceilings	F02	F02	165,432	0	2,174	16,130	118,152	0.71
Bldg. Envelope	Non Res/Non Sys	Insulate attic ceilings	NG	NG	6,457	0	85	272	-2,144	-0.33
Bldg. Envelope	Res	Insulate attic ceilings	F02	F02	226,888	0	137	1,019	-210,030	-0.93
Bldg. Envelope	Res	Insulate attic ceilings	NG	NG	507,808	0	13,346	68,063	536,020	1.06
Bldg. Envelope	Non Res/Non Sys	Ins walls of wood frame bldgs	F02	F02	8,073	0	32	241	-3,838	-0.48
Bldg. Envelope	Non Res/Non Sys	Ins walls of wood frame bldgs	NG	NG	2,643	0	11	34	-2,098	-0.79
Bldg. Envelope	Non Res/Sys	Ins walls of wood frame bldgs	F06	F06	3,195	0	13	85	-1,177	-0.37
Bldg. Envelope	Non Res/Sys	Ins walls of wood frame bldgs	NG	NG	10,255	0	41	86	-8,767	-0.85
Bldg. Envelope	Res	Ins walls of wood frame bldgs	F02	F02	11,073	0	1	9	-10,924	-0.99
Bldg. Envelope	Res	Ins walls of wood frame bldgs	NG	NG	29,143	0	118	601	-19,930	-0.68
Bldg. Envelope	Non Res/Non Sys	Ins int brick surface walls	F02	F02	9,446	0	88	655	2,064	0.22
Bldg. Envelope	Non Res/Non Sys	Ins int brick surface walls	NG	NG	8,969	0	84	268	-4,711	-0.53
Bldg. Envelope	Non Res/Sys	Ins int brick surface walls	F06	F06	29,195	0	272	1,781	13,319	0.46
Bldg Envelope	Non Res/Sys	Ins int brick surface walls	NG	NG	19,814	0	185	389	-11,807	-0.60
Bldg. Envelope	Res	Ins perimeter of slab	F02	F02	61	0	6	45	676	11.13
Bldg. Envelope	Res	Ins perimeter of slab	NG	NG	5,901	0	586	2,988	39,930	6.77
Bldg. Envelope	Non Res/Non Sys	Ins floor above crawl space	F02	F02	220,577	0	14,492	107,530	1,669,923	7.57
Bldg. Envelope	Non Res/Non Sys	Ins floor above crawl space	NG	NG	8,609	0	566	1,810	20,141	2.34
Bldg. Envelope	Non Res/Non Sys	Install storm windows	F02	F02	8,489	0	63	464	-325	-0.04
Bldg. Envelope	Non Res/Non Sys	Install storm windows	NG	NG	8,060	0	59	190	-5,040	-0.63
Bldg. Envelope	Non Res/Sys	Install storm windows	F06	F06	26,236	0	194	1,268	4,024	0.15
Bldg. Envelope	Non Res/Sys	Install storm windows	NG	NG	17,806	0	131	276	-12,121	-0.68
Bldg. Envelope	Non Res/Non Sys	Caulking and weatherstripping	F02	F02	671,555	0	1,019	7,558	-614,872	-0.92
Bldg. Envelope	Non Res/Non Sys	Caulking and weatherstripping	NG	NG	214,484	0	486	1,554	-203,762	-0.95
Bldg. Envelope	Non Res/Sys	Caulking and weatherstripping	F06	F06	711,110	0	1,683	11,026	-614,325	-0.86
Bldg. Envelope	Non Res/Sys	Caulking and weatherstripping	NG	NG	527,324	0	1,249	2,622	-504,933	-0.96
Bldg. Envelope	Res	Caulking and weatherstripping	F02	F02	30,500	0	72	536	-26,590	-0.87
Bldg. Envelope	Res	Caulking and weatherstripping	NG	NG	2,964,099	0	7,020	35,801	-2,719,215	-0.92

B.2.2 Analysis of Building Auxiliary Heating Measures

This section presents the analysis of the two auxiliary heating energy efficiency measures: 1) infrared heaters for limited spaces within both classes of non-residential buildings such as hangars, motor pools, and warehouses and 2) programmable setback thermostat controls.

Analytical Procedure

Energy-savings calculations developed for building auxiliary heating measures were derived from procedures in ASHRAE Fundamentals and from discussion with HVAC vendors concerning thermostat setback control devices. Both measures provide efficiency improvement over standard technologies. Infrared heaters are an effective method of selectively heating limited areas in large buildings such as hangars. They operate in a wide temperature range, from 300°F up to 5000°F. Because they heat as a radiative source using the infrared portion of light's spectrum, they heat only objects and not the medium that it must pass through to reach the object (i.e., air). This principle, along with the lower fan and pump needs, saves energy.

The programmable setback thermostat control devices now available are uncomplicated and user-friendly. These electronically controlled devices provide the means to set back the temperature when the space is unoccupied or when a greater (or no) deviation from the normal set-point temperature can be tolerated. This control technology is commonly used to replace mechanical, pin-operated setback thermostats. Space-heating savings are the result of lower energy use during periods when the temperature set point is reduced from the standard level.

Results

The results of the analysis of the auxiliary heating measures are located in Table B.2. One measure type was analyzed for both system and non-system natural gas fueled non-residential buildings, and one measure type was analyzed for residential buildings fueled by natural gas. All three cases had high positive net present values.

TABLE B.2. Building Auxiliary Heating Measures--Cost, Quantity and Value of Energy-Efficiency Improvements

Energy Conservation Measure Category	Sector	Energy Conservation Measure	Existing Fuel	Resulting Fuel	Initial Capital Cost (1991 $)	Present Value of O&M Costs (1991 $)	Annual Energy Savings (MBtu)	Value of Annual Energy Savings (1991 $)	NPV of Strategy (1991 $)	Value Index
Bldg. Aux. Heating	Non Res/Non Sys	Infrared heaters	NG	NG	68,414	0	12,083	38,665	563,381	8.23
Bldg. Aux. Heating	Non Res/Sys	Infrared heaters	NG	NG	55,533	0	8,760	18,396	245,074	4.41
Bldg. Aux. Heating	Res	Setback Thermostat Controls	NG	NG	218,155	0	19,374	98,809	1,297,193	5.95

B.2.3 Analysis of Water Heating Measures

This section discusses two water heating energy efficiency measures. The first measure is to install low-flow shower heads in the remaining available locations (about 30% of housing structures) and the second is to insulate DHW pipes.

Analytical Procedure

Energy savings calculations for both measures were derived from procedures in the ASHRAE Fundamentals. Inputs to calculating the performance of the low-flow shower heads included the extent of shower use and duration of shower. The algorithms developed for the insulation of DHW pipes accounted for convective, radiative, and conductive heat loss. For each measure, both the current and post-measure installation heat loss was calculated using the algorithms for the three heat loss modes. The difference between the two heat loss values is the energy savings. Important inputs to these algorithms included: affected pipe length (ft) and diameter (inch), ambient air and internal pipe temperature (°F), insulation thermal conductivity [Btu/(hrft°F)], and insulation thickness (inch).

Results

The results of the analysis of the water heating efficiency measures are located in Table B.3. Two measure types were analyzed for system and non-system non-residential buildings and for residential buildings. The analysis was conducted by fuel type within each of the building types, which provided for 10 cases for calculating measure energy savings, cost and net present value. All 10 cases had positive net present values.

B.2.4 Analysis of Boiler Measures

This section presents the 14 boiler efficiency measures that were considered. They are primarily measures where an energy saving device is installed (combustion air preheater, feedwater economizer, air atomizing burner and low excess air burner, flue gas analyzer, fire-tube turbulators) or maintenance of existing equipment is provided (boiler tune-up to optimize air-to-fuel ratios and maintenance of feedwater economizers).

TABLE B.3. Building Water Heating Efficiency Measures--Cost, Quantity and Value of Energy Efficiency Improvements

Energy Conservation Measure Category	Sector	Energy Conservation Measure	Existing Fuel	Resulting Fuel	Initial Capital Cost (1991 $)	Present Value of O&M Costs (1991 $)	Annual Energy Savings (MBtu)	Value of Annual Energy Savings (1991 $)	NPV of Strategy (1991 $)	Value Index
Water Heating	Non Res/Non Sys	Low-Flow Shower Heads	F02	F02	6,890	0	1,564	11,604	197,124	28.61
Water Heating	Non Res/Non Sys	Low-Flow Shower Heads	NG	NG	885	0	318	1,017	15,265	17.24
Water Heating	Non Res/Sys	Low-Flow Shower Heads	F06	F06	5,986	0	2,494	16,337	383,896	64.13
Water Heating	Non Res/Sys	Low-Flow Shower Heads	NG	NG	4,152	0	1,730	3,633	68,676	16.54
Water Heating	Res	Low-Flow Shower Heads	NG	NG	3,349	0	558	2,845	40,290	12.03
Water Heating	Non Res/Non Sys	Ins Service Hot Water Pipes	F02	F02	10,512	0	657	4,878	75,249	7.16
Water Heating	Non Res/Non Sys	Ins Service Hot Water Pipes	NG	NG	1,794	0	112	359	3,910	2.18
Water Heating	Non Res/Sys	Ins Service Hot Water Pipes	F06	F06	2,559	0	160	1,045	22,386	8.75
Water Heating	Non Res/Sys	Ins Service Hot Water Pipes	NG	NG	1,953	0	122	257	2,729	1.40
Water Heating	Res	Ins Service Hot Water Pipes	NG	NG	2,315	0	144	735	8,962	3.87

Analytical Procedure

Energy savings calculations developed for boiler measures were derived from contacts with vendors and from boiler operation handbooks. These measures provided efficiency improvements that were primarily based on boiler age and boiler stack temperatures. Previous boiler studies performed at the Fort provided useful information regarding these two measures. Boiler capacity (MBtu/hr) was an additional factor affecting the implementation of measures. Typically, the Fort Lewis main plant boilers for central steam distribution ranged between 5 and 60 MBtu/hr. The boilers dedicated to a building unit typically ranged in size from 0.2 to 1 MBtu/hr. Many of the measures, such as the combustion air preheater or feedwater economizers, capture and save energy by reducing boiler stack temperatures. Other measures, such as the boiler tuneup and oxygen trim controls, optimize the air-to-fuel ratios to provide for more energy efficient combustion.

Results

The results of the analysis of the boiler efficiency measures are located in Table B.4. There were 14 measures applied to non-residential buildings served directly by fuel oil and natural gas and those served by a district system, which provided for 38 cases in which the measure energy savings, cost, and net present value were calculated. Out of the 38 cases analyzed, 28 have positive net present values.

B.2.5 Analysis of District Thermal Distribution Measures

This section describes seven energy-efficiency measures for application to the district heat distribution systems, including repairing defective steam traps, insulating buried steam and above-ground distribution lines, locating and repairing steam mass loss in the distribution lines, water-to-water heat recovery in dining hall facilities, and insulating hot water storage tanks.

Analytical Procedure

Energy savings calculations developed for district thermal distribution measures were derived from district thermal distribution handbooks and contacts with vendors and a consulting expert with considerable district thermal

TABLE C.4. Boiler Efficiency Measures--Cost, Quantity and Value of Energy Efficiency Improvements

Energy Conservation Measure Category	Sector	Energy Conservation Measure	Existing Fuel	Resulting Fuel	Initial Capital Cost (1991 $)	Present Value of O&M Costs (1991 $)	Annual Energy Savings (MBtu)	Value of Annual Energy Savings (1991 $)	NPV of Strategy (1991 $)	Value Index
Boilers	Non Res/Sys	Preheat combustion air	F06	F06	286,043	0	3,457	22,645	254,384	0.89
Boilers	Non Res/Non Sys	Feedwater economizers	F02	F02	129	0	4	27	393	3.06
Boilers	Non Res/Non Sys	Feedwater economizers	NG	NG	3,639	0	102	326	1,546	0.42
Boilers	Non Res/Sys	Feedwater economizers	F02	F02	336	0	7	51	565	1.68
Boilers	Non Res/Sys	Feedwater economizers	F06	F06	90,991	0	2,310	15,130	270,081	2.97
Boilers	Non Res/Sys	Feedwater economizers	NG	NG	48,397	0	2,369	4,975	49,858	1.03
Boilers	Non Res/Non Sys	Air atom. burners/LEA burners	F02	F02	27,487,844	0	12,025	89,226	-25,919,148	-0.94
Boilers	Non Res/Sys	Air atom. burners/LEA burners	F02	F02	8,600	0	27	204	-4,996	-0.58
Boilers	Non Res/Sys	Air atom. burners/LEA burners	F06	F06	901,444	0	9,239	60,518	542,844	0.60
Boilers	Non Res/Sys	Flue gas analyzer	F06	F06	93,373	0	9,239	60,518	1,350,916	14.47
Boilers	Non Res/Sys	Flue gas analyzer	NG	NG	132,595	0	9,117	19,146	242,214	1.83
Boilers	Non Res/Non Sys	Boiler tuneup	F02	F02	0	5,467,850	7,123	52,850	-4,538,692	(a)
Boilers	Non Res/Non Sys	Boiler tuneup	NG	NG	0	1,600,064	5,006	16,018	-1,345,627	(a)
Boilers	Non Res/Sys	Boiler tuneup	F02	F02	0	1,558	22	163	1,515	(a)
Boilers	Non Res/Non Sys	Automatic electric dampers	F02	F02	174,924	0	11,722	86,974	1,354,188	7.74
Boilers	Non Res/Non Sys	Automatic electric dampers	NG	NG	46,410	0	7,496	23,987	334,607	7.21
Boilers	Non Res/Sys	Automatic electric dampers	F02	F02	47	0	22	163	2,835	59.95
Boilers	Non Res/Sys	Automatic electric dampers	F06	F06	5,618	0	4,184	27,407	648,447	115.41
Boilers	Non Res/Sys	Automatic electric dampers	NG	NG	4,514	0	6,480	13,608	270,771	59.98
Boilers	Non Res/Non Sys	Fire-tube turbulators	F02	F02	587	0	510	3,784	65,942	112.36
Boilers	Non Res/Non Sys	Fire-tube turbulators	NG	NG	1,176	0	721	2,307	35,472	30.16
Boilers	Non Res/Sys	Auto blowdown w/ heat recovery	F06	F06	218,914	0	5,544	36,311	647,659	2.96
Boilers	Non Res/Sys	Auto blowdown w/ heat recovery	NG	NG	200,928	0	5,470	11,487	23,944	0.12
Boilers	Non Res/Non Sys	Oxygen trim control	F02	F02	11,974,577	16,403,558	3,708	27,513	-27,894,421	-2.33
Boilers	Non Res/Non Sys	Oxygen trim control	NG	NG	3,504,142	4,800,203	2,669	8,542	-8,168,669	-2.33
Boilers	Non Res/Sys	Oxygen trim control	F02	F02	3,010	4,1[illegible]	14	106	-5,253	-1.75
Boilers	Non Res/Sys	Oxygen trim control	F06	F06	130,722	179,072	4,805	31,470	441,236	3.38
Boilers	Non Res/Sys	Oxygen trim control	NG	NG	224,623	307,706	4,926	10,345	-328,032	-1.46
Boilers	Non Res/Sys	Maintenance of economizers	F02	F02	336	0	7	51	565	1.68
Boilers	Non Res/Sys	Maintenance of economizers	F06	F06	90,991	0	2,310	15,130	270,081	2.97
Boilers	Non Res/Sys	Maintenance of economizers	NG	NG	79,573	0	2,369	4,974	18,661	0.23

(a) Value Index not defined, because capital cost is zero.

operating experience at the campus of UCLA. The calculations of energy savings involving insulation of pipes and hot water storage tanks follows ASHRAE Fundamentals principles and is discussed in Section 2.3.1. Insulation and repair of buried distribution pipes included additional costs associated with locating leaks with infrared detection devices and excavation. Energy savings calculated for the water-to-water heat recovery devices in the dining halls included standard heat transfer calculations with required ıputs of flow rates, operation schedule, temperature differences between the discharged water and incoming water, and estimated heat recovery potential with the heat exchanger.

Results

The results of the analysis of the district thermal distribution system measures are located in Table B.5. There were seven measures applied to the district thermal distribution system, which provided 18 cases in which the measure energy savings, cost, and net present value were calculated. Fifteen of the 18 cases had positive net present values.

B.2.6 Analysis of Fuel-Switching Opportunities

This section describes three fuel-switching opportunities: two relate to switching old oil-fired boilers to a conventional gas-fired boiler or a gas pulse combustion boiler; the third involves replacing conventional electric water heaters with specially lined gas water heaters.

Analytical Procedure

Replacing the old oil boilers with new gas boilers, whether with conventional gas boilers or gas pulse combustion boilers, will result in increased efficiency and energy savings. However, because an electric water heater is nominally 100% efficient, and a gas water heater is between 75% and 95% efficient, there will be no energy (Btu) savings for delivery of the same quantity of hot water with this measure. The benefit of this measure, however, is in lower fuel cost due to the lower cost per Btu of natural gas.

TABLE B.5. District Thermal Distribution System Efficiency Measures--Cost, Quantity and Value of Energy Efficiency Improvements

Energy Conservation Measure Category	Sector	Energy Conservation Measure	Existing Fuel	Resulting Fuel	Initial Capital Cost (1991 $)	Present Value of O&M Costs (1991 $)	Annual Energy Savings (MBtu)	Value of Annual Energy Savings (1991 $)	NPV of Strategy (1991 $)	Value Index
Dist. Thermal Distrib.	Non Res/Non Sys	Inspection of Steam Traps	F02	F02	0	468,071	675	5,005	-380,070	(a)
Dist. Thermal Distrib.	Non Res/Non Sys	Inspection of Steam Traps	NG	NG	0	227,593	329	1,052	-210,888	(a)
Dist. Thermal Distrib.	Non Res/Sys	Inspection of Steam Traps	F02	F02	0	524	1	6	-421	-42,083,738.79
Dist. Thermal Distrib.	Non Res/Sys	Inspection of Steam Traps	F06	F06	0	346,152	499	3,266	-268,217	(a)
Dist. Thermal Distrib.	Non Res/Sys	Inspection of Steam Traps	NG	NG	0	225,560	325	682	-210,538	(a)
Dist. Thermal Distrib.	Non Res/Sys	Ins buried pipe-main dist line	F02	F02	202	0	9	69	1,020	5.06
Dist. Thermal Distrib.	Non Res/Sys	Ins buried pipe-main dist line	F06	F06	133,221	0	6,167	40,397	830,864	6.24
Dist. Thermal Distrib.	Non Res/Sys	Ins buried pipe-main dist line	NG	NG	86,807	0	4,019	8,440	99,177	1.14
Dist. Thermal Distrib.	Non Res/Non Sys	Ins above grnd dist pipe	F02	F02	71,604	0	14,213	105,463	1,782,553	24.89
Dist. Thermal Distrib.	Non Res/Non Sys	Ins above grnd dist pipe	NG	NG	34,815	0	6,911	22,114	316,456	9.09
Dist. Thermal Distrib.	Non Res/Sys	Ins above grnd dist pipe	F02	F02	80	0	16	118	2,006	25.06
Dist. Thermal Distrib.	Non Res/Sys	Ins above grnd dist pipe	F06	F06	94,952	0	30,469	199,572	4,667,884	49.16
Dist. Thermal Distrib.	Non Res/Sys	Ins above grnd dist pipe	NG	NG	44,056	0	13,265	27,856	474,328	10.77
Dist. Thermal Distrib.	Non Res/Sys	Insulate Hot Fuel Oil Pipes	F06	F06	37,715	0	4,186	27,418	616,612	16.35
Dist. Thermal Distrib.	Non Res/Sys	Minimize Losses in Steam Lines	F02	F02	35	0	4	28	454	13.12
Dist. Thermal Distrib.	Non Res/Sys	Minimize Losses in Steam Lines	F06	F06	103,976	0	19,580	128,246	2,956,654	28.44
Dist. Thermal Distrib.	Non Res/Sys	Minimize Losses in Steam Lines	NG	NG	31,541	0	5,098	10,705	198,346	6.29
Dist. Thermal Distrib.	Non Res/Non Sys	Water-to-water heat exchanger	F02	F02	4,506	0	106	784	9,285	2.06
Dist. Thermal Distrib.	Non Res/Sys	Water-to-water heat exchanger	F06	F06	36,323	0	4,903	32,115	730,103	20.10
Dist. Thermal Distrib.	Non Res/Sys	Water-to-water heat exchanger	NG	NG	5,255	0	2,262	4,750	109,725	20.88
Dist. Thermal Distrib.	Non Res/Non Sys	Ins Hot Water Storage Tanks	F02	F02	158,330	0	14,018	104,010	1,670,286	10.55
Dist. Thermal Distrib.	Non Res/Non Sys	Ins Hot Water Storage Tanks	NG	NG	76,984	0	6,816	21,813	269,492	3.50
Dist. Thermal Distrib.	Non Res/Sys	Ins Hot Water Storage Tanks	F02	F02	177	0	16	116	1,871	10.57
Dist. Thermal Distrib.	Non Res/Sys	Ins Hot Water Storage Tanks	F06	F06	117,089	0	10,366	67,899	1,503,337	12.84
Dist. Thermal Distrib.	Non Res/Sys	Ins Hot Water Storage Tanks	NG	NG	76,292	0	6,754	14,184	236,274	3.10

(a) Value Index not defined, because capital cost is zero.

Results

The results of the analysis of the three fuel-switching opportunities are provided in Table B.6. The opportunities were applicable to all three building types and provided nine cases in which the energy use change, cost, and net present value were calculated. Energy use is projected to increase in four of the cases, yet one of these had a positive net present value. Four additional cases exhibit positive net present values, for a total of five.

B.2.7 Energy Analysis Results Summary

Of the 110 cases analyzed, 72 have positive net present values. Five of these were dropped due to competing measures that have higher net present values. The remaining 67 measures are displayed in Table B.7 with their estimated initial capital cost, present value of operation and maintenance costs, annual energy savings, value of annual energy savings, net present value, and value index. These are sorted by application to each of the four sectors--district system, non-residential non-system buildings, non-residential system buildings, and residential buildings.

B.3 ENERGY RESOURCE OPPORTUNITIES IMPACT SUMMARY

The total cost-effective fossil-fuel efficiency resource at Fort Lewis amounts to over 319,000 MBtu, a reduction of approximately 18% of all the fossil fuel consumed in 1989. Acquiring all of the cost-effective resource would be an investment with an estimated net present value of approximately $41.6 million. The annual fuel expenditure savings, evaluated at 1991 fuel prices, would be over $2.3 million. Table B.8 summarizes the cost-effective efficiency resource by end-use sector and by fuel type. In the context of this discussion, the cost-effective resource includes all energy conservation investments that have a positive NPV.

TABLE B.6. Fuel-Switching Opportunities--Cost, Quantity, and Value

Energy Conservation Measure Category	Sector	Energy Conservation Measure	Existing Fuel	Resulting Fuel	Initial Capital Cost (1991 $)	Present Value of O&M Costs (1991 $)	Annual Energy Savings (MBtu)	Value of Annual Energy Savings (1991 $)	NPV of Strategy (1991 $)	Value Index
Fuel Switch	Non Res/Non Sys	Oil to conv gas boiler	F02	NG	1,820,371	0	2,768	227,323	2,593,182	1.42
Fuel Switch	Non Res/Sys	Oil to conv gas boiler	F06	NG	129,568	0	134	40,096	1,021,642	7.88
Fuel Switch	Non Res/Non Sys	Oil to gas pulse boiler	F02	NG	4,503,593	0	4,104	229,588	-59,412	-0.01
Fuel Switch	Non Res/Non Sys	Elec to gas DHW - CR	ELC	NG	282,757	-231,686	-1,908	47,400	344,164	1.22
Fuel Switch	Res	Elec to gas DHW - CR	ELC	NG	1,288,765	-1,055,993	-9,126	87,528	-312,455	-0.24
Fuel Switch	Non Res/Non Sys	Elec to gas DHW - ROF	ELC	NG	246,882	168,968	-1,908	47,400	-119,642	-0.48
Fuel Switch	Res	Elec to gas DHW - ROF	ELC	NG	1,125,251	-954,059	-9,126	87,528	-377,662	-0.34
Fuel Switch	Non Res/Non Sys	Infrared heaters	F02	NG	81,406	0	7,642	239,459	4,519,407	55.52
Fuel Switch	Non Res/Sys	Infrared heaters	F06	NG	68,647	0	7,962	252,940	7,023,987	102.32

TABLE B.7. Energy-Efficiency and Fuel-Switching Measures Having Positive Net Present Values, by Sector

	Energy-Use Reduction (MBtu)										
	Natural Gas	Fuel Oil #2	Fuel Oil #6	Elec-tricity	Total	Initial Cap. Cost (1991 $)	Present Value of O&M Costs (1991 $)	Annual Energy Savings (MBtu)	Value of Annual Energy Savings (1991 $)	NPV of Strategy (1991 $)	Value Index
District System											
District Thermal Distrib.											
Ins buried pipe-main dist line	0	9	0	0	9	202	0	9	69	1,020	5.06
Ins above grnd dist pipe	0	16	0	0	16	80	0	16	118	2,006	25.06
Water-to-water heat exchanger	2,262	0	0	0	2,262	5,255	0	2,262	4,750	109,725	20.88
Ins Hot Water Storage Tanks	0	16	0	0	16	177	0	16	116	1,871	10.57
Minimize Losses in Steam Lines	0	0	19,580	0	19,580	103,976	0	19,580	128,246	2,956,654	28.44
Minimize Losses in Steam Lines	0	4	0	0	4	35	0	4	28	454	13.12
Insulate Hot Fuel Oil Pipes	0	0	4,186	0	4,186	37,715	0	4,186	27,418	616,612	16.35
Minimize Losses in Steam Lines	5,098	0	0	0	5,098	31,541	0	5,098	10,705	198,346	6.29
Ins Hot Water Storage Tanks	0	0	10,366	0	10,366	117,089	0	10,366	67,899	1,503,337	12.84
Ins above grnd dist pipe	13,265	0	0	0	13,265	44,056	0	13,265	27,856	474,328	10.77
Ins Hot Water Storage Tanks	6,754	0	0	0	6,754	76,292	0	6,754	14,184	236,274	3.10
Ins buried pipe-main dist line	4,019	0	0	0	4,019	86,807	0	4,019	8,440	99,177	1.14
Ins buried pipe-main dist line	0	0	6,167	0	6,167	133,221	0	6,167	40,397	830,864	6.24
Water-to-water heat exchanger	0	0	4,903	0	4,903	36,323	0	4,903	32,115	730,103	20.10
Ins above grnd dist pipe	0	0	30,469	0	30,469	94,952	0	30,469	199,572	4,667,884	49.16
Subtotal	31,398	45	75,671	0	107,113	767,721	0	107,113	561,912	12,428,655	16.19
Non Residential/Non System											
Bldg. Aux. Heating											
Infrared heaters	12,083	0	0	0	12,083	68,414	0	12,083	38,665	563,381	8.23
Bldg. Envelope											
Ins floor above crawl space	0	14,492	0	0	14,492	220,577	0	14,492	107,530	1,669,923	7.57
Ins floor above crawl space	566	0	0	0	566	8,609	0	566	1,810	20,141	2.34
Ins int brick surface walls	0	88	0	0	88	9,446	0	88	655	2,064	0.22
Insulate attic ceilings	0	2,174	0	0	2,174	165,432	0	2,174	16,130	118,152	0.71
Insulate suspended ceilings	0	1,010	0	0	1,010	56,628	0	1,010	7,494	75,131	1.33
Boilers											
Automatic electric dampers	7,496	0	0	0	7,496	46,410	0	7,496	23,987	334,607	7.21
Feedwater economizers	102	0	0	0	102	3,639	0	102	326	1,546	0.42
Fire-tube turbulators	721	0	0	0	721	1,176	0	721	2,307	35,472	30.16
Ins above grnd dist pipe	0	14,213	0	0	14,213	71,604	0	14,213	105,463	1,782,553	24.89
Ins above grnd dist pipe	6,911	0	0	0	6,911	34,815	0	6,911	22,114	316,456	9.09
Ins Hot Water Storage Tanks	6,816	0	0	0	6,816	76,984	0	6,816	21,813	269,492	3.50
Ins Hot Water Storage Tanks	0	14,018	0	0	14,018	158,330	0	14,018	104,010	1,670,286	10.55
Water-to-water heat exchanger	0	106	0	0	106	4,506	0	106	784	9,285	2.06

TABLE B.7. (contd)

	Energy-Use Reduction (MBtu) Natural Gas	Fuel Oil #2	Fuel Oil #6	Elec-tricity	Total	Initial Cap. Cost (1991 $)	Present Value of O&M Costs (1991 $)	Annual Energy Savings (MBtu)	Value of Annual Energy Savings (1991 $)	NPV of Strategy (1991 $)	Value Index
Fuel Switch											
Elec to gas DHW - CR	-14,587	0	0	12,679	-1,908	282,757	-231,686	-1,908	47,400	344,164	1.22
Infrared heaters	-43,358	51,000	0	0	7,642	81,406	0	7,642	239,459	4,519,407	55.52
Oil to conv gas boiler	-49,060	51,827	0	0	2,768	1,820,371	0	2,768	227,323	2,593,182	1.42
Water Heating											
Ins Service Hot Water Pipes	0	657	0	0	657	10,512	0	657	4,878	75,249	7.16
Ins Service Hot Water Pipes	112	0	0	0	112	1,794	0	112	359	3,910	2.18
Low Flow Shower Heads	0	1,564	0	0	1,564	6,890	0	1,564	11,604	197,124	28.61
Low Flow Shower Heads	318	0	0	0	318	885	0	318	1,017	15,265	17.24
Subtotal	-71,880	151,150	0	12,679	91,948	3,131,186	-231,686	91,948	985,129	14,616,789	4.67
<u>Non Residential/System</u>											
Bldg. Aux. Heating											
Infrared heaters	8,760	0	0	0	8,760	55,533	0	8,760	18,396	245,074	4.41
Bldg. Envelope											
Ins int brick surface walls	0	0	272	0	272	29,195	0	272	1,781	13,319	0.46
Install storm windows	0	0	194	0	194	26,236	0	194	1,268	4,024	0.15
Insulate suspended ceilings	0	0	821	0	821	46,360	0	821	5,375	81,917	1.77
Boilers											
Air atom. burners/LEA burners	0	0	9,239	0	9,239	901,444	0	9,239	60,518	542,844	0.60
Auto blowdown w/ heat recovery	5,470	0	0	0	5,470	200,928	0	5,470	11,487	23,944	0.12
Auto blowdown w/ heat recovery	0	0	5,544	0	5,544	218,914	0	5,544	36,311	647,659	2.96
Automatic electric dampers	6,480	0	0	0	6,480	4,514	0	6,480	13,608	270,771	59.98
Automatic electric dampers	0	22	0	0	22	47	0	22	163	2,835	59.95
Automatic electric dampers	0	0	4,184	0	4,184	5,618	0	4,184	27,407	648,447	115.41
Boiler tuneup	0	22	0	0	22	0	1,368	22	163	1,515	(a)
Feedwater economizers	2,369	0	0	0	2,369	48,397	0	2,369	4,975	49,858	1.03
Feedwater economizers	0	0	2,310	0	2,310	90,991	0	2,310	15,130	270,081	2.97
Feedwater economizers	0	7	0	0	7	336	0	7	51	565	1.68
Flue gas analyzer	9,117	0	0	0	9,117	132,595	0	9,117	19,146	242,214	1.83
Flue gas analyzer	0	0	9,239	0	9,239	93,373	0	9,239	60,518	1,350,916	14.47
Maintenance of economizers	2,369	0	0	0	2,369	79,573	0	2,369	4,974	18,661	0.23
Maintenance of economizers	0	7	0	0	7	336	0	7	51	565	1.68
Maintenance of economizers	0	0	2,310	0	2,310	90,991	0	2,310	15,130	270,081	2.97
Oxygen trim control	0	0	4,805	0	4,805	130,722	179,072	4,805	31,470	441,236	3.38

TABLE B.7. (contd)

	Energy-Use Reduction (MBtu)										
	Natural Gas	Fuel Oil #2	Fuel Oil #6	Electricity	Total	Initial Cap. Cost (1991 $)	Present Value of O&M Costs (1991 $)	Annual Energy Savings (MBtu)	Value of Annual Energy Savings (1991 $)	NPV of Strategy (1991 $)	Value Index
Fuel Switch											
Infrared heaters	-45,121	0	53,083	0	7,962	68,647	0	7,962	252,940	7,023,987	102.32
Water Heating											
Ins Service Hot Water Pipes	0	0	160	0	160	2,559	0	160	1,045	22,386	8.75
Ins Service Hot Water Pipes	122	0	0	0	122	1,953	0	122	257	2,729	1.40
Low Flow Shower Heads	0	0	2,494	0	2,494	5,986	0	2,494	16,337	383,896	64.13
Low Flow Shower Heads	1,730	0	0	0	1,730	4,152	0	1,730	3,633	68,676	16.54
Subtotal	-8,704	58	94,654	0	86,008	2,239,400	180,440	86,008	602,134	12,628,201	5.64
Residential											
Bldg. Aux. Heating											
Setback Thermostat Controls	19,374	0	0	0	19,374	218,155	0	19,374	98,809	1,297,193	5.95
Bldg. Envelope											
Ins perimeter of slab	586	0	0	0	586	5,901	0	586	2,988	39,930	6.77
Ins perimeter of slab	0	6	0	0	6	61	0	6	45	676	11.13
Insulate attic ceilings	13,346	0	0	0	13,346	507,808	0	13,346	68,063	536,020	1.06
Water Heating											
Ins Service Hot Water Pipes	144	0	0	0	144	2,315	0	144	735	8,962	3.87
Low Flow Shower Heads	558	0	0	0	558	3,349	0	558	2,845	40,290	12.03
Subtotal	34,008	6	0	0	34,014	737,588	0	34,014	173,485	1,923,070	2.61
TOTAL	-15,179	151,258	170,325	12,679	319,084	6,875,895	-51,246	319,084	2,322,660	41,596,716	6.05

(a) Value Index not defined, because capital cost is zero.

TABLE B.8. Annual Cost-Effective Fossil-Fuel Efficiency Resource By Sector and Fuel Type

	Energy-Use Reduction (MBtu)	New Load (MBtu)	Net Energy-Use Reduction (MBtu)	Initial Capital Cost (1991 $)	Value of Annual Energy Savings (1991 $)	NPV of Strategy (1991 $)
By Sector (including fuel-switching)						
District System	107,113	0	107,113	767,721	561,912	12,428,655
Non-Residential/Non-System	198,953	107,005	91,948	3,131,186	985,129	14,616,789
Non-Residential/System	131,129	45,121	86,008	2,239,400	602,134	12,628,201
Residential	34,014	0	34,014	737,588	173,485	1,923,070
TOTAL	471,210	152,126	319,084	6,875,895	2,322,660	41,596,716
By Fuel						
Fuel Oil #2	48,430	0	48,430	705,199	359,189	5,609,758
Fuel Oil #6	117,242	0	117,242	2,165,664	767,936	15,982,261
Natural Gas	136,947	0	136,947	1,751,850	428,251	5,522,441
Fuel-Switching (elec to gas)	12,679	14,587	-1,908	282,757	47,400	344,164
Fuel-Switching (#2 to gas)	102,828	92,418	10,410	1,901,778	466,782	7,112,589
Fuel-Switching (#6 to gas)	53,083	45,121	7,962	68,647	252,940	7,023,987
TOTAL	471,210	152,126	319,084	6,875,895	2,322,497	41,595,201

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